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The Causal Relationship between Money Supply, Inflation, and Industrial Production in India: Vector Error Correction Estimation

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Abstract

Both Keynesians and monetarists believe that inflation is caused by an increase in aggregate demand, which is caused by an increase in the money supply. The most significant impact of inflation is to distort relative prices, and savings, investment, and the fiscal balance. Though inflation is generally associated negatively with economic growth, there may also possibly be a threshold or positive effect of price rise on industrial growth, and thereby, on the economy. This paper examines the long- and short-run causal relationship between inflation, money supply, and industrial output in India over the period 1981 to 2020, applying the vector error correction mechanism (VECM) approach. The unit root tests show that the index of industrial production, reserve money, and consumer price index are stationary at the second difference, and the Johansen cointegration test reveals that the variables are cointegrated. The coefficient of the error correction term in the VECM estimates is negative, significantly in the inflation equation, and insignificantly in the output and money supply equations. The VECM results reveal short-run causality between money supply and industrial production, showing disequilibrium in the short-run relationship between industrial production, inflation, and money supply, and quick adjustment towards the long-run equilibrium. The speed of adjustment in the inflation equation is 24 per cent. Therefore, about 24 per cent of the short-run deviation, i.e. disequilibrium, in the inflation-growth relationship is adjusted every year.

Keywords: Industrial Production, Money Supply, Inflation, Causality, VECM Estimation

Introduction

Inflation is a sustained increase in the general price level of goods and services in an economy over a period of time. When the price level rises, each unit of currency buys fewer goods and services, reflecting a reduction in the purchasing power per unit of money. That is, there is a loss of real value in the medium of exchange and unit of account within the economy. The inflation rate is the chief measure of price inflation, which depicts the annualised percentage change in a general price index, generally the consumer price index, over time. Low or moderate inflation is mostly attributed to fluctuations in real demand for goods and services or changes in available supplies, such as during scarcities. However, the consensus view is that a long sustained period of inflation or hyper-inflation is caused by the money supply growing faster than the rate of economic growth. However, growth in money supply need not necessarily cause inflation.

Both Keynesians and monetarists believe that inflation is caused by an increase in aggregate demand, which in turn is caused by an increase in the supply of money. The higher the growth rate of the nominal money supply, the higher the rate of inflation. An increase in the disposable income of people raises their demand for goods and services, and thereby the inflation rate. Disposable income may increase with the rise in national income or reduction in taxes or reduction in the savings of the people. An increase in consumer spending raises the demand for goods due to conspicuous consumption, demonstration effect, and the easy availability of credit, hire-purchase, and instalment facilities. Inflation is also caused by government or public expenditure. Increasing government activities raises government expenditure, which in turn raises aggregate demand for goods and services, thus eventually causing inflation. A cheap monetary policy, credit expansion, deficit financing, repayment of public debt, and increased

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exports lead to an increase in money supply and money in circulation, raising the demand for goods, which leads to inflationary prices. Other channels of price rise include the expansion of the private sector causing a rise in income and employment and hence, income and black money that increases extravagant spending, raising unnecessary demand for goods that pushes the prices further.

On the supply side, certain factors that operate on the opposite side of aggregate demand tend to reduce the aggregate supply of goods, such as shortage of raw materials like labour, raw materials, power supply, capital, and so on; industrial disputes that lead to lock-outs curtailing production and supply of goods; and natural calamities like drought or floods. More exports relative to domestic demand creates shortage of goods in the domestic market, leading to inflation in the economy. Even lop-sided production, such as the production of luxurious goods, neglecting basic and essential consumer goods, creates shortages and stress on consumer goods in the market, causing inflation. If industrial production is characterised by traditional and outdated technologies of production, the law of diminishing returns operates, raising the cost per unit of production, thereby raising the prices of products. Further, in the globalised context of the world economy, when prices rise in major industrial countries, their effects spread to almost all countries with which they have trade relations. Often the rise in the price of basic raw materials like crude oil in the international market leads to a rise in the prices of all related domestic goods.

Inflation could hamper economic growth, as the economy suffers from relative price distortions and the economy is not able to fully adjust to the rate of inflation. Nominal interest rates are often controlled, and hence real interest rate becomes negative and volatile, discouraging savings. Depreciation of exchange rates lags behind inflation, resulting in variability in real appreciations and exchange rates. Real tax collection does not keep up with inflation, because collections are based on the nominal income of the earlier year, and public utility prices are not raised in line with inflation. For both reasons, the fiscal problem is intensified by inflation, and public savings may be reduced, adversely affecting public investment. High inflation is unstable. There is uncertainty about the future rates of inflation, which reduces the efficiency of investment and discourages potential investors.

The adverse impact of inflation on growth could operate and manifest through multiple channels. High inflation and the resultant higher inflation differential relative to the inflation in the rest of the world could cause the real effective exchange rate to appreciate, which in turn could weaken export growth. The most significant impact of inflation could be on private investment and even productivity of investment. Inflation could cause misallocation of financial resources, from productive investment to speculative activities. It may discourage domestic savings, expansion of credit, and more debt than more savings could become the norm in a high inflation regime. Specific fiscal measures taken to contain inflation could delay fiscal consolidation, and fiscal imbalance may increase. Revenue collection may lag behind due to lags in the pricing of public utilities, as well as incentives to under-report income to escape inflation tax. Fiscal imbalance is a risk to both inflation and growth. Anti-inflationary monetary policy in response to inflation could raise the cost of financing for investment and consumption activities, and thereby compress aggregate demand. Overall, the impact of inflation on the economy is mostly negative and spirals inflation itself further.

Given the generally depressing effect of inflation on the economy, and possibly a threshold effect on economic growth, the study examines the causal relationship between inflation, money supply, and industrial production in India. The study period is from 1981 to 2020, and the relevant data are derived from the Reserve Bank of India and the World Bank database. Empirically, this study uses the Vector Error Correction (VECM) approach to estimate the long- and short-run relationship among the variables.

Review of Literature

Bruno and Easterly (1998) analyse the relationship between inflation and economic growth in 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 about a 40 per cent threshold inflation to have a significant effect on growth.

They find that growth falls sharply during discrete high inflation crises, then recovers rapidly and strongly after inflation falls.

Ghosh and Phillips (1998) estimate the relationship between inflation and growth in 145 countries, over 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 in 4 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 in all 4 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 speeds up growth; however, faster economic growth feeds back into inflation.

Burdekin et al. (2004) analyse the effect of inflation on growth in 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 Organisation 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 reveal significant evidence of similar behaviour for APEC countries.

Jha and Dang (2012) examine the relationship between inflation variability and growth, covering the period 1961 to 2009, in 182 developing countries and 31 developed countries, using 2-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, and 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.

Gullapalli (2013) analyses the non-linear effects of inflation on growth in 2l4 countries for the period 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 as follows: for low-income countries 14.5%, lower-middle-income countries 9%, upper-middle-income countries 10%, high-income countries 2.25%, fast-growing countries 16%, and slow-growing countries 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 only in high inflation thresholds.

In specific country settings, Faria and Carneiro (2001) examine the relationship between inflation and output, both in short and long runs, 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 2 variables run one way, from GDP growth to inflation.

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 is applied to examine the long-run relationship between inflation and its determinants. The error correction estimates reveal the existence of both short- and long-run relationship in Nepal. The error correction model is stable and robust.

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 the cointegrating relationship and the direction of causality are examined. The existence of a cointegration relationship between the 2 series is detected by the Bound's 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, but a negative and statistically significant short-term relationship between inflation and 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, and an increase in money supply increases growth and that growth causes inflation. However, an increase in money in circulation need not necessarily increase the general price level in the economy.

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 increases 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.

In the Indian context, Balakrishnan (1991) made 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-reform 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 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 inflation surge trends 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 and, 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 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 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 6% 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, nominal exchange rate of rupee with respect to 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's 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 in 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 1996-97Q1-1997 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 is encumbered, as the case for the existence of the Phillips curve in India further weakens.

Data and Methodology

The data used in this study on output growth, money supply, and inflation, for the period 1981 to 2020, are derived from the Reserve Bank of India and World Bank database sources. The output growth is measured by the index of industrial production (IIP), money supply by reserve money, and inflation by consumer price index (CPI). The lIP is a composite index that measures the short-term changes in the volume of production in the various sectors of the economy. The reserve money, the monetary base of the country, is defined as the portion of the reserves of the commercial banks that are maintained in accounts with the Central Bank, plus the total currency circulating in the public. The CIP measures the inflation rate, the rate at which the general level of prices for goods and services is rising and consequently the purchasing power of currency is falling.

Error Correction Model

Stationarity: Any time series data has to be stationary for analysis. Econometric analysis of time series variable is subjected to many tests before estimation. A series is strictly stationary if the distribution of its values remains the same as time progresses, implying that the value of the variable within a particular interval is the same now as at any time in the past or future. A strictly stationary process is one where for any $t_i \in z$, any $k \in z$, and t = 1, ..., T:

$$F\left(y_{t_1}, y_{t_2} \dots y_{t_T}\right)(y_1 \dots y_T) = F\left(y_{t_1+k}, y_{t_2+k} \dots y_{t_T+k}\right)(y_1 \dots y_T) \quad (1)$$

Where, F denotes the joint distribution function of the set of random variables. In terms of probability, the probability measure for the sequence $\{y_T\}$ is the same as that for $\{y_{T+k}\}\ \forall k$. A weak stationary or covariance stationary process is when a series satisfies:

$$E(y_t) = \mu,\ E[(y_t - \mu)(y_t - \mu)] = \sigma^2,$$
$$E\left[\left(y_{t_i} - \mu\right)\left(y_{t_j} - \mu\right)\right] = y_{t_i - t_j} \forall t_i, t_j \quad (2)$$

Thus, a stationary process should have a constant mean, constant variance, and constant auto-covariance structure.

Augmented Dickey-Fuller Unit Root Test: A time series is non-stationary if the mean, variance, and auto-covariance keep changing with time. Depending on the nature of the time series, it may be represented as:

$$\Delta y_t = \delta y_{t-1} + u_t$$
$$\Delta y_t = \alpha + \delta y_{t-1} + u_t$$
$$\Delta y_t = \alpha + \beta t + \delta y_{t-1} + u_t \quad (3)$$

The Augmented Dickey-Fuller (ADF) test under the null of non-stationarity can be conducted to test whether a given series is stationary or not. This test is conducted by augmenting either of the above 3 equations by adding the lagged value of the dependent variable Δy_t:

$$\Delta y_t = \delta y_{t-1} + \lambda \sum_{i=1}^{n} \Delta y_{t-1} + u_t$$
$$\Delta y_t = \alpha + \delta y_{t-1} + \lambda \sum_{i=1}^{n} \Delta y_{t-1} + u_t$$
$$\Delta y_t = \alpha + \beta t + \delta y_{t-1} + \lambda \sum_{i=1}^{n} \Delta y_{t-1} + u_t \quad (4)$$

Where, u is a pure-white noise error and the number of lagged difference term to include is determined empirically. If $\delta = 0$, the series is non-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.

Cointegration Test: The existence of a long-run relationship between any 2 time series, i.e. cointegration between the variables, is checked by the Johansen and Engle-Granger cointegration tests. If both time series integrated are of the same order, then the 2 series can be represented by cointegrating equations as:

$$y_t = a_{11} + b_{11} x_t + \varepsilon_{yt}$$
$$x_t = a_{21} + b_{21} y_t + \varepsilon_{xt} \quad (5)$$

Where, the residuals ε_{yt} and ε_{xt} measure the extent to which y and x are out of equilibrium. If ε_{yt} and ε_{xt} integrated are of order zero, i.e. I(0), then both y_t and x_t are cointegrated and not expected to remain apart in the long run, and the regression on the same levels of the 2 variables is meaningful and not spurious; no long-run information is lost. If cointegration exists, the information on one variable can be used to predict the other. The long-run or equilibrium relationship between the 2 series exists only if they are stationary or if each series integrated are of the same order I(d). The cointegration between the variables is tested using the Eigen value and trace statistics.

Trace Test: The trace test tests the null hypothesis of r cointegrating relations against the alternative of k cointegrating relations, where k is the number of endogenous variables, for r = 0, 1,…, k-1. The alternative of k cointegrating relations corresponds to the case where none of the series has a unit root. The trace statistic for the null hypothesis of r cointegrating relations is computed as:

$$LR_{tr}(r|k) = -T\sum_{i=r+1}^{k}\ln(1-\gamma_i) \quad (6)$$

Where, T is the sample size and γ_i is the ith largest Eigen value.

Maximum Eigen Value Test: The maximum Eigen value test tests the null hypothesis of r cointegrating relations against the alternative of r+1 cointegrating relations. This test statistic is computed as, for r = 0, 1, …, k-1:

$$LR_{max}(r|r+1) = -T\log(1-\gamma_{r+1}) = LR_{tr}(r|k) - LR_{tr}(r+1|k) \quad (7)$$

Where, T is the sample size and γ_i is the ith largest Eigen value. The cointegration test hypotheses for both tests are:

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

Where, 'r' implies cointegrating relation.

If the absolute value of the computed trace statistic and computed Eigen value 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 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 Eigen value, the null hypothesis is either accepted or rejected.

Both variables are to be checked for the stationarity property before using the Johansen cointegration test. The stationarity test allows for higher autocorrelation in residuals:

$$\Delta y_t = \alpha_1 + \delta_1 y_{t-1} + \lambda_1\sum_{i=1}^{n} y_{t-i} + \varepsilon_{yt} \quad (8)$$

$$\Delta x_t = \alpha_2 + \delta_2 x_{t-1} + \lambda_2\sum_{i=1}^{n} y_{t-i} + \varepsilon_{xt} \quad (9)$$

Where, ε_{yt} and ε_{xt} are covariance stationary random error terms. The lag length n is determined by the Akaike information criteria (AIC) to ensure serially uncorrelated residuals and n is decided according to Newly-West suggestions. The null hypothesis of non-stationarity is tested using the Mackinnon t-statistics.

Causality Test: The existence of co-relationship between variables does not necessarily imply causation or the direction of influence. The Granger causality test allows the determining of the short-run or forecasting direction of the relations between the variables. In the 2-variable relations model, the Granger causality test postulates that y and x are affected by their own lags and the lags of the other variable:

$$y_t = \sum_{i=1}^{n}\delta_i x_{t-i} + \sum_{i=1}^{n}\lambda_1 y_{t-j} + \varepsilon_{yt} \quad (10)$$

$$x_t = \sum_{i=1}^{n}\delta_i y_{t-i} + \sum_{j=1}^{n}\lambda_{1_j} x_{t-j} + \varepsilon_{xt} \quad (11)$$

There are 2 null hypotheses in the case of a 2-variable system: H_0: one variable does not Granger cause the other against the alternative hypothesis; (H_a): a variable Granger causes the other. The coefficients are jointly tested for their significance to determine the direction of causality.

Error Correction Mechanism: If the variables are cointegrated, then there must exist a long-run relationship and, therefore, error correction method (ECM) has to be followed. The ECM takes the following form:

$$\Delta y_t = \theta_1\Delta x_{t-j} + \sum_{i=1}^{q}\theta_2\Delta y_{t-i} + \rho_1\tau_{t-1} + \varepsilon_{yt} \quad (12)$$

$$\Delta x_t = \theta_3\Delta y_{t-j} + \sum_{i=1}^{s}\theta_4\Delta x_{t-i} + \rho_2\omega_{t-1} + \varepsilon_{xt} \quad (13)$$

Where, Δ denotes the first difference operator, τ and ω are error correction terms, q and s are the number of lag lengths (determined by AIC), and ε_{yt} and ε_{xt} are random disturbance terms. For the series to be related within a structural ECM, i begins at one and j begins at zero. The error correction terms τ and ω measure deviations of the series from the long-run equilibrium relations. For the series to converge to the long-run equilibrium relation, $0 \leq \rho \leq 1$ should hold. However, cointegration implies that not all ρ should be zero.

Empirical Analysis

Unit Root Test: The results of the ADF unit root test presented in Table 1 reject the null hypothesis of no unit root, i.e. the given series is stationary at levels. All variables become stationary at the second difference. The serial correlation and heteroscedasticity test results do not reject the null hypothesis of no serial correlation and heteroscedasticity.

Table 1: Augmented Dickey-Fuller Stationarity Test

Variable	*At Level*			*At First Difference*			*At Second Difference*		
	None	*Intercept*	*Intercept + Trend*	*None*	*Intercept*	*Intercept + Trend*	*None*	*Intercept*	*Intercept + Trend*
IIP	1.86 (0.98)	0.51 (0.98)	−1.71 (0.72)	−1.81*** (0.07)	−3.02** (0.04)	−3.19*** (0.10)	−6.63* (0.00)	−6.51* (0.00)	−6.57* (0.00)
RM	4.41 (1.01)	3.80 (1.02)	2.13 1.03)	2.22 (0.99)	−1.58 (0.48)	−2.68 (0.25)	−10.2* (0.00)	− 1 0 . 6 * (0.00)	−3.64** (0.04)
CPI	−1.52 (0.11)	−3.98* (0.00)	−3.91* (0.02)	−6.33* (0.00)	−6.24* (0.00)	−6.19* (0.00)	−8.80* (0.00)	−8.63* (0.00)	−8.67* (0.00)

Note: *, **, *** significant at 1, 5, 10% levels.

Table 2: Serial Correlation and Heteroscedasticity Tests

Breusch-Godfrey Serial Correlation LM Test		*Breusch-Pagan-Godfrey Heteroscedasticity Test*	
F-statistic	1.500	F-statistic	1.388
Obs*R squared	3.876	Obs*R squared	11.564
Prob. F	0.246	Prob. F	0.255
Prob. chi-square	0.144	Prob. chi-square	0.239
		Scaled explained SS	6.962
		Prob. chi-square	0.641

Cointegration Test: The Johansen cointegration test tests the null hypothesis of no cointegration between the variables. The results of the unrestricted cointegration rank test, the trace, and maximum Eigen value tests presented in Table 3 could not reject the null hypothesis of no cointegration and, therefore, the alternative hypothesis that there is cointegration or long-run relationship among the variables is to be accepted.

Table 3: Johansen Cointegration Test

Hypothesised No. of CE (s)	*Trace Test*				*Maximum Eigen Value Test*			
	Eigen Value	*Trace Statistic*	*5% Critical Value*	*Prob.***	*Eigen Value*	*Max. Eigen Statistic*	*5% Critical Value*	*Prob.***
r = 0	0.676	48.173*	29.797	0.000	0.676	34.927*	21.131	0.000
r ≤ 1	0.279	13.246	15.495	0.106	0.279	10.149	14.264	0.202
r ≤ 2	0.095	3.097	3.841	0.078	0.095	3.097	3.841	0.078

Note: Trace test indicates one cointegrating equation at the 0.05 level. *Rejection of the hypothesis at the 0.05 level. **MacKinnon-Hang-Michelis p-values.

Granger Causality Test: The Granger causality checks the short-run causality running from the independent variable to the dependent variable. The testing hypotheses are: Null H_0: Lagged values of coefficients in each equation are zero; and Alternative H_1: Lagged values of coefficients are not zero. The Granger causality test is performed using the Wald chi-square statistics. The Granger causality results presented in Table 4 show that there is no short-run causality running from the lags of independent variables to dependent variables. The lagged variables of CPI and IIP in the CPI equation are statistically significant. This indicates that there is a short-run causality running from CPI and reserve money to IIP. Similarly, significance of the lagged value of IIP and reserve money in the reserve money equation indicates that there is a short-run causality running from the IIP and reserve money to the reserve money. However, there is no short-run causality running from the lagged values of all the 3 variables to the IIP.

Table 4: Granger Causality Test

Independent Variable	*Dependent Variable*		
	CPI	*IIP*	*RM*
CPI	9.257*** (0.009)	0.310 (0.856)	1.085 (0.581)
IIP	10.793** (0.004)	3.673 (0.159)	11.634** (0.003)
RM	0.619 (0.734)	0.270 (0.874)	13.046* (0.000)

Note: Chi-square values. p-values in parentheses. *, **, ** significant at 1, 5, 10% levels.

Vector Error Correction Model Estimates: Table 5 presents the vector error correction model estimates. The coefficient of the error correction term reflects the self-correcting dynamic mechanism. The sign of error correction term is negative and statistically significant in inflation equation. The error terms in the index of industrial production and reserve money equations are negative, but not statistically significant. As the estimated ECT shows, the speed of adjustment in the inflation equation is 24%. Therefore, about 24% of the short-run deviation, i.e. disequilibrium in the inflation-growth relationship, is adjusted every year.

Table 5: Vector Error Correction Estimates of IIP, Reserve Money, and CPI

Cointegrating Equations			
CPI(−1)	1.000		
IIP(−1)	−0.060 (0.026) [−2.307]		
RM(−1)	0.001(0.0008) [1.418]		
Constant	0.894		
Variable	D(CPI)	D(IIP)	D(RM)
ECT	−2.430* (0.439) [5.511]	−1.423 (3.176) [0.448]	−15.185 (46.402) [0.327]
D(CPI(−1))	0.841*** (0.306) [2.748]	1.181 (2.212) [0.534]	20.780 (32.324) [0.643]
D(CPI(−2))	0.263 (0.170) [1.553]	0.652 (1.226) [0.531]	17.759 (19.920) [0.991]
D(IIP(−1))	−0.126* (0.038) [3.284]	−0.492 (0.278) [1.772]	13.081** (4.060) [3.219]
D(IIP(−2))	−0.075 (0.055) [1.362]	−0.542 (0.396) [1.364]	1.262 (5.804) [0.217]
D(RM(−1))	0.001 (0.002) [0.667]	0.003 (0.015) [0.225]	−0.625*** (0.223) [2.802]
D(RM(−2))	0.0008 (0.001) [0.699]	−0.002 (0.009) [2.882]	−0.644* (0.135) [4.781]
Constant	0.088 (0.510) [0.173]	0.010 (3.687) [0.002]	100.809 (53.876) [1.871]
R-square	0.799	0.260	0.812
Adjusted R-square	0.723	0.024	0.752
F-statistics	11.821	1.102	13.547
Log-likelihood	−68.468	−127.822	−208.274
Akaike AIC	5.098	9.055	14.418
Schwarz SC	5.471	9.428	14.792

Note: Standard errors in parentheses. Absolute t-values in square brackets. *, **, ** significant at 1, 5, 10% levels.

Conclusion

The economics literature on the relationship between inflation and economic growth generally subscribes to the depressing effect of inflation on the economy, and possibly a threshold effect on economic growth. This study employs the time series method to study the causal relationship between inflation, money supply, and output in India using the data for the period 1981-2020. The unit root test results of this study show that the variables index of industrial production, reserve money, and consumer price index are not stationary at levels, but stationary at the second difference. The Johansen cointegration test shows that the variables are cointegrated. The vector error correction model results show that the coefficient of the error correction term in the inflation equation is negative and statistically significant. The coefficient of error correction terms in the output and money supply equations are negative but insignificant. There exists a short-run causality in both equations. The disequilibrium among the variables is adjusted quickly towards the long-run equilibrium. The speed of adjustment in the inflation equation is 24%. Therefore, about 24 per cent of the short-run deviation, i.e. disequilibrium in the inflation-growth relationship, is adjusted every year.

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