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## THE IMPACT OF MONETARY POLICY ON OUTPUT AND INFLATION IN INDIA: A FREQUENCY DOMAIN ANALYSIS<sup>1</sup>

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**ABSTRACT:** *In the recent past, several attempts by the RBI to control inflation through tight monetary policy have ended up slowing the growth process, thereby provoking prolonged discussion among academics and policymakers about the efficacy of monetary policy in India. Against this backdrop, the present study attempts to estimate the causal relationship between monetary policy and its final objectives; i.e., growth, and controlling inflation in India. The methodological tool used is testing for Granger Causality in the frequency domain as developed by Lemmens et al. (2008), and monetary policy has been proxied by the weighted average call money rate. In view of the fact that output gap is one of the determinants of future inflation, an attempt has also been made to study the causal relationship between output*

*gap and inflation. The results of empirical estimation show a bi-directional causality between policy rate and inflation and between policy rate and output, which implies that the monetary authorities in India were equally concerned about inflation and output growth when determining policy. Furthermore, any attempt to control inflation affects output with the same or even greater magnitude than inflation, thereby damaging the growth process. The relationship between output gap and inflation was found to be positive, as reported in earlier studies for India. Furthermore, the output gap causes inflation only in the short-to-medium-run.*

**KEY WORDS:** *Granger Causality, Frequency Domain, Monetary Policy, Output Gap.*

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## **1. INTRODUCTION**

In the past few years, the growth-inflation trade-off and the subsequent role of monetary policy in India has provoked prolonged debates among Indian policymakers and academics (Mohanty 2013), as high inflation and low growth have coexisted. This is contrary to conventional economic theory, which suggests that low inflation helps accelerate the real growth of the economy by stimulating overall consumption and investment. It is also important to note that high growth leads to high inflation, following the Phillips curve (Phillips 1958), which depicts a short-term direct relationship between growth and inflation (i.e., high growth in the short-run gives rise to inflationary pressures). As a result, there has been a wide consensus among economic thinkers that monetary policy should have the single objective of low and stable inflation, so that by anchoring inflation expectations in the desired way, monetary policy can create an environment conducive to growth (Rajan and Prasad 2008).

However, in the recent past it has been observed that the several attempts by the Reserve Bank of India (RBI) to contain inflation through tight money policy have failed, and eventually ended up slowing the growth process. Thus, the persistently high inflation in India along with low growth has become a puzzle for the monetary authorities (Mohanty 2013). Needless to say, this inflation inflicts a real cost on the economy as its major burden is borne by the poor, which eventually leads to distributional inequalities (Mohanty 2013, 2014). Also, persistently high inflation beyond a particular threshold level could pose serious challenges to growth in the long-run (Mohaddes and Raissi 2014).

The Phillips curve also implies a positive link between output gap and inflation. It is important to note that both the level of and changes in the output gap affect inflation. Monetary policy decisions are based on different indicators that provide vital information on future inflation and output growth. In monetary policy the output gap can be used as one of the indicators of inflation. Therefore the important task for policymakers is to study the link between output gap and inflation and thereby ensure the required changes in policy rates. Against this backdrop, the present study uses the Granger Causality in the frequency domain approach developed by Lemmens et al. (2008) to first test the impact of monetary policy on output and inflation, and to then analyse the relationship between output gap and inflation in India, thus providing essential information

regarding the prevailing output gap and inflation dynamics. Also, Structural Vector Auto-Regression (SVAR) is used to discover the structural relationships between monetary policy rate, inflation, and output in India. The study covers the sample period from January 2002 to December 2015.

The novelty of the present study lies in the fact that it uses the frequency domain Granger Causality method as proposed by Lemmens et al. (2008) to test the effectiveness of monetary policy in India. The use of this methodology is justified in the methodology section (5). First, the causality between both policy rate and inflation and policy rate and output is estimated. Then the causality between output gap and inflation is tested. The Structural Vector Auto-Regression (SVAR) model is used to estimate the structural relationship between monetary policy shock, inflation, and output growth in India.

The rest of the paper is organised as follows. Section 2 reviews the literature, section 3 analyses the trend in the variables under study, section 4 gives the data sources and the scheme of empirical estimation, section 5 covers the methodology, section 6 briefs about the results of the empirical estimation and its analysis, and section 7 concludes.

## **2. LITERATURE REVIEW**

The literature review in this paper is divided into two sections. The first section comprises existing theoretical literature on the impact of monetary policy on inflation and output in India and abroad and output gap and inflation ; i.e., the Phillips curve relationship in India. The second section reviews existing literature on Granger causality in the frequency domain.

### **2.1. Monetary policy, output, and inflation**

The effectiveness of monetary policy is tested through its ability to achieve the final objectives of growth and price stability. An extensive literature examines the impact of monetary policy on growth and inflation in India, as well as in other countries. This research attempts to empirically test the strength and effectiveness of each of the channels of monetary policy transmission, separately through different econometric techniques. However, the results are mixed.

A number of international studies have analysed the effectiveness of monetary policy by testing the different channels of monetary transmission. Romer and Romer (1990), while explaining monetary policy transmission, point out the role of credit market imperfections in macroeconomic fluctuation and the transmission of monetary policy to aggregate demand. They find that the impact of monetary policy on interest rates occurs largely through the liabilities side (transaction balances) rather than the assets side (lending) of banks' balance sheets. Bernanke and Gertler (1995) highlight the importance of the credit channel in the monetary transmission process. They call the monetary transmission process a "black box" because there are different channels of monetary transmission operating simultaneously, making it difficult to separately pin down the impact of each channel. Mishkin (1996) provides an overview of the various channels of monetary transmission, along with the lessons to be followed by monetary authorities in the conduct of monetary policy. The study emphasises the empirical failure of the interest rate channel. D'Arista (2009) focuses on the 2008 financial crisis and the failure of monetary policy to handle the crisis. The author recommends a new asset-based reserve management system to rebuild the transmission mechanism of monetary policy, thereby making it a more effective economic weapon.

Most of the studies analysing the impact of monetary policy on either aggregate demand or inflation and output in the Indian context show that monetary policy has a significant impact on output and inflation (Al-Mashat 2003; Aleem 2010; Mohanty 2012; Khundrakpam 2012, 2013), and conclude that tight monetary policy has a negative impact on growth and inflation, whereas loose monetary policy has a positive impact. However, the transmission of monetary policy to the final objectives occurs with a lag.

Khundrakpam and Jain (2012) estimate the impact of monetary policy on inflation and GDP growth in India by using the SVAR model for the period 1996-1997:Q1 to 2011:Q1. The study illustrates that a positive shock to the policy rate leads to a slowdown in credit growth with a lag of two quarters, which eventually has a negative impact on GDP growth and inflation.

Kapur and Behera (2012) analyse the impact of monetary policy on output and inflation in India during the period 1996:Q1 to 2011:Q4. They find a significant

impact of monetary policy on output and inflation, but a modest impact on inflation.

Nachane, Ray, and Ghosh (2002) explore whether monetary policy has a similar impact across the different Indian states. They found that the core states, i.e., the states with greater concentration of manufacturing units and relatively well-developed banking infrastructure, tend to be more sensitive to monetary policy shocks than the others.

Ghosh (2009), examining the response of India's industrial output to monetary policy shocks, finds that the impact of monetary policy shocks on industrial output differs across industries. Similarly, Singh and Rao (2014) examine the impact of monetary policy shocks on output in India at the aggregate level and sector-wise output level for the period 1996:Q1 to 2013:Q4. They find that the impact of monetary policy on output differs across economic sectors. Furthermore, the relevance of each channel of monetary transmission varies across sectors. The study thus demonstrates the need for sector-specific monetary policy in India.

In contrast to the studies mentioned above, Bhattacharya, Patnaik, and Shah (2011) find weak monetary policy transmission in India, in line with other low-income economies that have a small, weak financial sector. Their evidence shows that the interest rates do not affect aggregate demand. However, the study suggests that the interest rates can impact inflation in the presence of strong exchange rate pass-through.

The existing literature demonstrates that monetary policy does have an impact on output and inflation in India, but with a lag. Furthermore, the impact of monetary policy is short-lived, and it differs across sectors of the economy.

## **2.2 Output gap and inflation**

Conventional economic theory suggests a positive relationship between output gap and inflation, as summarized in the Phillips curve (Phillips 1958). Output gap is defined as deviation of actual output from its potential level, where potential output is the level of output at which the rate of inflation is stable, given the productive stock of capital. Potential output demonstrates the supply

side of the economy in the form of the level of production at normal utilization of factors of production, given the current state of technology. Potential output is thus determined by the availability of factors of production and technological progress. Since prices are sticky in the short-run, demand shocks provoke supply reaction, causing actual output to differ from its potential level. A persistent positive output gap (real output above potential level) indicates mounting inflationary pressures due to excess demand in the economy, which in turn necessitates a tight monetary policy to smoothen the aggregate demand pressures. Conversely, a negative output gap (real output below potential level) denotes deflationary pressures in the economy, as aggregate supply exceeds demand, necessitating a loose monetary policy to fuel aggregate demand. Therefore, output gap provides monetary policy with an essential signal. Like ups and downs in GDP growth, the output gap can move in either a positive or a negative direction, which is undesirable. An output gap suggests that the economy is working inefficiently, either overusing or underusing its resources. Since output gap is one of the significant determinants of inflation, it has immediate implications for monetary policy. The output gap differs during the different phases of the business cycle, provoking a prompt response from monetary authorities. In an inflation-targeting framework, a negative output gap, indicating a fall in actual output below its potential (full capacity) level, results in a deflationary pressure on prices. Under these circumstances the central bank has to stop inflation falling below the target level by lowering interest rates to increase aggregate demand, which eventually leads to higher output growth. The opposite happens when the output gap is positive, building upward pressure on prices: the central bank has to change interest rates by looking at the deviations of actual output from potential output. Since potential output and the output gap are unobservable directly, they are estimated from the data.

It is important to note that in the Indian context, research has found an asymmetric relation between output gap and inflation. The existing literature suggests two contradictory views regarding the existence of the Phillips curve and the positive relationship between output gap and inflation. One group of studies shows that a positive relationship between output gap and inflation as depicted in the Phillips curve does exist in India (Paul 2009; Singh, Kanakaraj, and Sridevi 2011; Mazumder 2011; Seth and Kumar 2012). In the other group of

studies, Bhalla (1981) finds no relationship between output gap and inflation, while other studies find evidence of a negative relationship between output gap and inflation, in contrast to conventional economic theory (Rangarajan 1983; Bhattacharya and Lodh 1990; Callen and Chang 1999). Furthermore, Brahmananda and Nagaraju (2002) find a negative correlation coefficient for inflation and output growth. Virmani (2004), analysing different methods of calculating the output gap for India, finds a negative relationship between output gap and inflation in one of the outcomes. Thus, the above-mentioned literature provides mixed views regarding the relationship between output gap and inflation in India.

### **2.3 Granger causality in the frequency domain**

Pierce (1979) and Geweke (1982) propose two alternative approaches to decomposing causality between two time series over the spectrum. While Pierce (1979) decomposes an R-squared measure for time series at each frequency over the spectrum, Geweke (1982) suggests the spectral representation of a bivariate Vector Autoregressive (VAR) time series model. Hosoya (1991) and Yao and Hosoya (2000) propose various testing procedures for Geweke's spectral Granger Causality approach. Breitung and Candelon (2006) develop a simple testing procedure for causality across frequencies by imposing linear restrictions on the autoregressive parameters in a bivariate VAR framework. Lemmens et al. (2008) reconsider the Pierce (1979) approach and develop a new non-parametric testing procedure for the same, and compare the size and power properties of their test with that of Breitung and Candelon (2006).

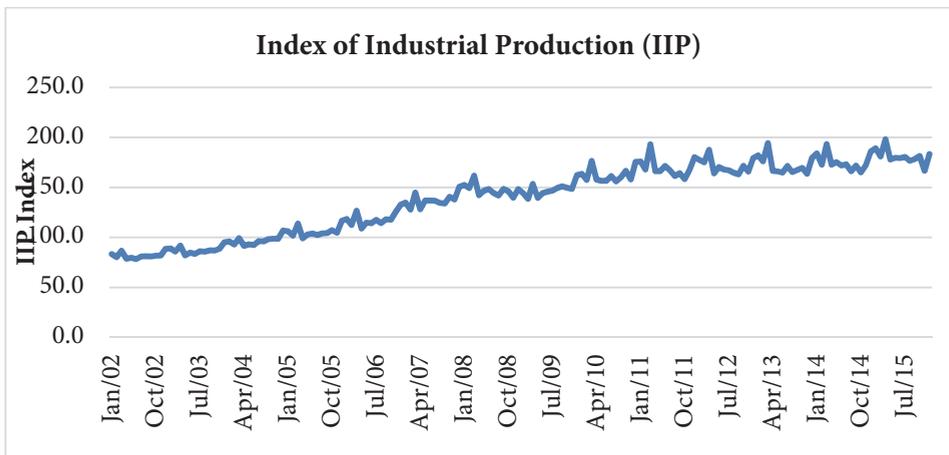
Few studies in the Indian context are based on frequency domain analysis. They include Nachane and Lakshmi (2001), Sharma, Kumar, and Hatekar (2010), Tiwari (2012), and Hatekar and Patnaik (2016). Tiwari (2012), using the Lemmens et al. (2008) approach, analyses the Granger causality in the frequency domain between producers' prices measured by the Wholesale Price Index (WPI), and consumer' prices measured by the Consumer Price Index (CPI), during the period January 1957 to February 2009. The study provides evidence of unidirectional causality going from CPI to WPI for business cycles of 12 months and beyond and business cycles of two or less months. Also, evidence of bidirectional causality between WPI and CPI is found for business cycles of five and four months. Sharma, Kumar, and Hatekar (2010) explore the causality

relationship between money, output, and prices for the period 1997 to 2009. Analysing the Granger causality in the Lemmens et al. (2008) frequency domain setup, they find unidirectional causality running from money supply (M3) to output (IIP) and money supply (M3) to Prices (WPI). However, the money supply Granger causes the output only in short-run, whereas the causality running from money supply to prices exists only at the business cycle frequencies. Hatekar and Patnaik (2016) investigate the causal relationship between CPI-IW and WPI in India using spectral analysis. They find a bi-directional causality between CPI-IW and WPI in India. Nachane and Lakshmi (2001) apply evolutionary spectrum technique to study the time-varying lag length and lag coefficients of monetary policy.

### 3. TRENDS OF THE VARIABLES UNDER STUDY

A peek into the time series plot of the variables under study provides essential insights. Figure 1 shows the movements in the Index of Industrial Production (IIP) series over the sample period (January 2002 to December 2015). It can be seen from the plot in Figure 1 that the IIP was almost stable for the first two years (2002 to 2004) of the sample period. Post-2004 it shows an upward trend. The index illustrates the high growth during the 2006 to 2010 period. During this period the economy also registered high growth.

**Figure 1:** Index of Industrial Production (IIP) (Base 2004-2005)

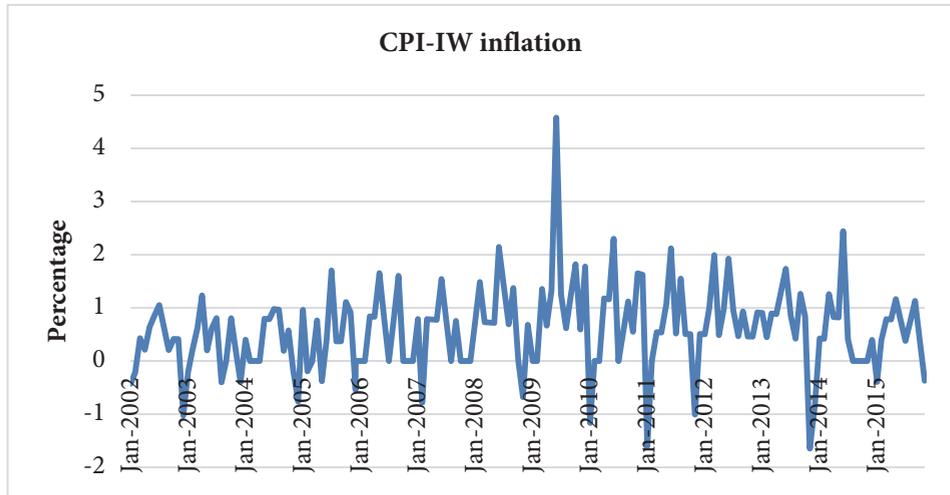


**Source:** Central Statistical Organisation (CSO), Govt. of India

However, post-2010 the index grows at a slower pace, with highly volatile movements. This indicates the subdued performance of the economy in the last few years.

Similarly, Figure 2 depicts the time path of Consumer Price Index for Industrial Workers (CPI-IW) inflation (month-on-month) for the period under study. It can be seen that m-o-m CPI-IW inflation was highest in the mid-2009 period. On a few occasions prices actually fell, as shown by the negative inflation. However, for most months the inflation was in the positive zone.

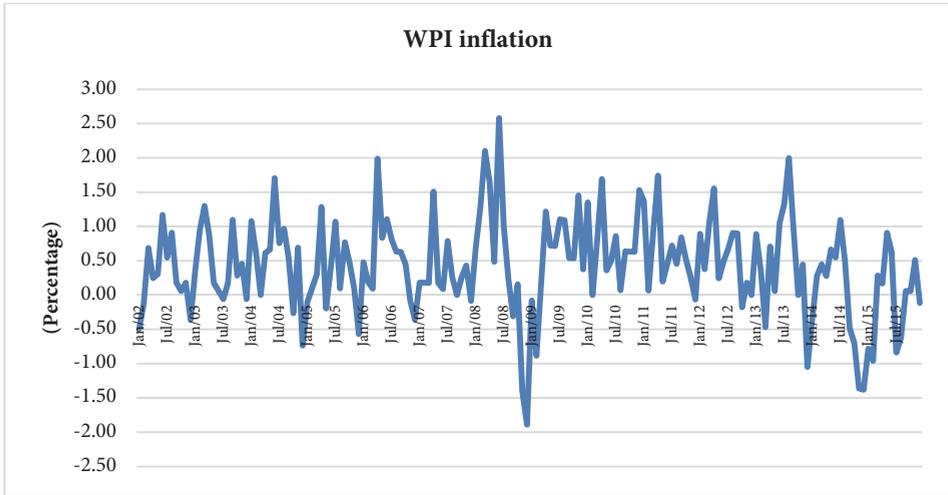
**Figure 2:** Consumer Price Index for Industrial Workers (CPI-IW) inflation (Base 2001)



Source: Reserve Bank of India (RBI)

The time series plot of Wholesale Price Index (WPI) (m-o-m) inflation is depicted in Figure 3 below. It can be seen from Figure 3 that WPI inflation is highly volatile in the sample period. It remains in a positive zone for a substantial period, but in the post-2014 period it shows frequent movements towards a negative value.

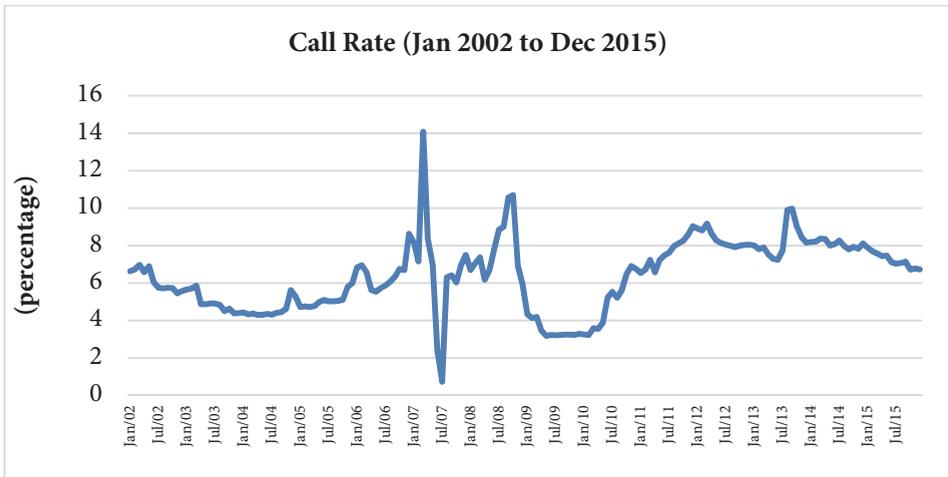
**Figure 3:** Wholesale Price Index (WPI) inflation (Base 2004-2005)



**Source:** Central Statistical Organisation (CSO), Govt. of India

To analyse the monetary policy stance over a period of time, the present study uses the weighted average call rate as a proxy for the monetary policy rate. Figure 4 depicts the path of the call rate from January 2002 to December 2015.

**Figure 4:** Movements in the call rate



**Source:** Reserve Bank of India (RBI)

The movements in the call rate illustrate the different phases of monetary policy expansion and contraction during the sample period. In the initial two years (2003 to 2004) there is a gradual fall in the call rate, which captures the expansionary stance of monetary policy. The next few years show a tightening phase in monetary policy as the call rate shows a gradual upward movement. However, in the post-2008 (post-crisis) period the call rate falls sharply, as in that period monetary policy was highly expansionary, to stimulate the economy. Monetary policy continued in an expansionary mode until 2010. However, in the post-2010 period, when rising inflation posed the biggest threat to the economy, monetary policy switched to a contractionary mode. Hence, there is continuous upward movement in the call rate, signifying a tight monetary policy.

#### **4. DATA SOURCES AND SCHEME OF EMPIRICAL ESTIMATION**

The present study primarily analyses the causality between:

- 1) monetary policy rate and inflation
- 2) policy rate and output
- 3) output gap and inflation in India using the frequency domain causality approach developed by Lemmens et al. (2008)

To supplement the causality analysis, SVAR analysis was also performed. To estimate the above-mentioned causal relationships, month-on-month CPI-IW inflation was taken as a proxy for overall retail inflation. Month-on-month WPI inflation was used to capture producer-level inflation, and the Index of Industrial Production (IIP) proxies for the output. The weighted average call rate was used as a proxy for the monetary policy rate. The study uses monthly data for the period January 2002 to December 2015. Data for the IIP and WPI was sourced from the Central Statistical Organisation (CSO) Government of India and the call rate and CPI-IW data were obtained from the RBI's Database on Indian Economy. The old CPI-IW, WPI, and IIP indices were spliced with the new indices to bring them to the recently revised common base year.

The monetary policy framework and operating procedure in India underwent significant changes during the sample period. A liquidity adjustment facility (LAF) was introduced in the early 2000s to manage day-to-day liquidity in the system through repo and reverse-repo operations. The monetary policy signals were provided through repo as well as reverse-repo rates. Hence, during conditions of excess liquidity the reverse-repo rate was the effective policy rate, whereas in tight liquidity conditions the repo rate was the effective policy rate. Therefore the policy rate switched between the repo rate and the reverse-repo rate (Kapur and Behera 2012). As a result, a single rate was needed to signal the monetary policy position, the monetary-policy-operating framework was modified, and a new operating framework came into effect in May 2011. In the new framework the repo rate became the single independently varying policy-rate to signal the policy position, and the weighted average overnight call money rate was explicitly recognised as the operating target of monetary policy, as the transmission of monetary policy signals to this segment was faster than to the other money market segments (RBI report 2011). Therefore, the present study uses the weighted average call rate as a proxy for the policy rate, as it moves in tandem with the effective policy rate; i.e., either repo or reverse-repo rate as the case may be, depending on the prevailing liquidity conditions.

The empirical estimation in the study involves the following steps:

- I. Testing the data for stationarity.
- II. Testing the data for seasonality (results not reported).
- III. Calculating the output gap.
- IV. Granger Causality testing in the frequency domain.
  - a) Causality between the monetary policy rate and inflation.
  - b) Causality between the monetary policy rate and output.
  - c) Causality between the output gap and inflation.
- V. SVAR analysis of the policy rate, output growth, inflation, and output gap.

## **5. METHODOLOGY**

### **5.1 Hodrick-Prescott Filter to derive the output gap**

Since potential output and output gap are unobservable directly, they are estimated from a given data. There are a number of methods to estimate

potential output and the output gap. Measures of the output gap are derived from different statistical and structural techniques such as the Hodrick-Prescott Filter (1997), the Kalman Filter, the production function approach, etc. The statistical methods use statistical criteria to decompose the output data into cyclical and trend components, where the output gap is measured as the difference between the actual output and the underlying trend. The HP filter is a popular statistical technique for measuring output gap. It decomposes output into a long-run trend and cyclical components. The trend is interpreted as a measure of potential output, while the cyclical components measure the output gap. This statistical method does not use any inputs regarding the determinants of each of the components. The present study uses the Hodrick-Prescott (HP) filter to calculate the output gap in the Indian economy. The HP filter is a pure statistical technique and suffers from major limitations, one of which is an arbitrary choice of  $\lambda$ , a smoothing parameter which determines the variance of the trend output estimate. Since the data used in the present study is of monthly frequency, the  $\lambda$  was set to equal 129,600.

## **5.2 Granger causality in the frequency domain**

Granger (1969) developed a time-series-data-based approach to test the causal relationship between variables in econometric models. According to this approach, the variable X Granger-causes variable Y if variable Y can be better predicted using the past values of both X and Y than it can be predicted using the past values of Y alone. To understand the link between economic variables, studying the pattern of causality in different time horizons becomes important.

In the frequency domain, a stationary process can be expressed as a weighted sum of sinusoidal components with a certain frequency. These frequency components can be analysed separately as quickly moving components representing short-term movements and slowly moving components denoting long-term movements (Lemmens, Croux, and Dekimpe 2008). Furthermore, the analysis of a time series in the frequency domain can provide information supplementary to that obtained through time domain analysis (Granger 1969; Priestley 1981). Since the extent and direction of causality can differ between frequency bands (Granger and Lin 1995), the conventional time domain causality approach fails to account for this changing extent and direction of causality between frequencies (Lemmens et al. 2008). Granger (1969) also

suggests that a spectral density approach provides a better and more complete picture than a one-shot Granger Causality (GC) measure that is applied across all periodicities (e.g., in the short-run, over the business cycle frequencies, and in the long-run). Hence, instead of computing a single one-shot GC measure for the full causal relationship, the GC is calculated for each individual frequency separately, thus helping us to decompose the GC in the frequency domain.

To proceed with the Lemmens et al., (2008) approach to calculating the Granger Causality (GC) measure, the autoregressive moving average (ARMA) filtered innovation series was used for all the variables. The selected lag length incorporated into the analysis was  $M=\sqrt{T}$  (Diebold, 2001), where ‘T’ is the number of observations. The study follows Sharma, Kumar, and Hatekar (2010), Tiwari (2012), and Hatekar and Patnaik (2016) in details regarding the Lemmens et al. (2008) approach. The frequency domain analysis methodology (Lemmens et al. 2008) was taken directly from the above-mentioned studies.

Lemmens et al. (2008) reconsider the Pierce (1979) Granger causality approach and propose a new non-parametric testing procedure for the same. Let  $X_t$  and  $Y_t$  be two stationary time series of length T. The goal is to test whether  $X_t$  Granger causes  $Y_t$  at a given frequency  $\lambda$ . Frequency domain analysis is performed on the univariate innovation series  $u_t$  and  $v_t$ , derived from filtering  $X_t$  and  $Y_t$  as univariate ARMA processes. The derived innovation series  $u_t$  and  $v_t$  are white noise processes with zero mean, possibly correlated with each other at different leads and lags.

Let  $S_u(\lambda)$  and  $S_v(\lambda)$  be the spectral density functions, or spectra, of  $u_t$  and  $v_t$  at frequency  $\lambda \in ]0, \pi [$ , defined by

$$S_u(\lambda) = \frac{1}{2\pi} \sum_{k=-\infty}^{\infty} \gamma_u(k) e^{-i\lambda k} \tag{1}$$

$$S_v(\lambda) = \frac{1}{2\pi} \sum_{k=-\infty}^{\infty} \gamma_v(k) e^{-i\lambda k} \tag{2}$$

where  $\gamma_u(k) = \text{Cov}(u_t, u_{t-k})$  and  $\gamma_v(k) = \text{Cov}(v_t, v_{t-k})$  represent the autocovariances of  $u_t$  and  $v_t$  at lag  $k$ . The idea of the spectral representation is that each time series may be decomposed into a sum of uncorrelated components, each related to a particular frequency  $\lambda$ .<sup>1</sup> The spectrum can be interpreted as a decomposition of the series variance by frequency. The portion of series variance occurring between any two frequencies is given by the area under the spectrum between these two frequencies. In other words, the area under  $S_u(\lambda)$  and  $S_v(\lambda)$ , between any two frequencies  $\lambda$  and  $\lambda + d\lambda$ , gives the portion of variance of  $u_t$  and  $v_t$  respectively, due to cyclical components in the frequency band  $(\lambda, \lambda + d\lambda)$ .

The cross-spectrum represents the cross-covariogram of two series in the frequency domain. It allows determining the relationship between two time series as a function of frequency. Let  $S_{uv}(\lambda)$  be the cross-spectrum between the  $u_t$  and  $v_t$  series. The cross-spectrum is a complex number, defined as

$$S_{uv}(\lambda) = C_{uv}(\lambda) + iQ_{uv}(\lambda)$$

$$= \frac{1}{2\pi} \sum_{k=-\infty}^{\infty} \gamma_{uv}(k) e^{-i\lambda k} \quad (3)$$

where  $C_{uv}(\lambda)$  is called the cospectrum and  $Q_{uv}(\lambda)$  is called the quadrature spectrum. These are the real and imaginary parts of the cross-spectrum respectively, and  $i = \sqrt{-1}$ . Here  $\gamma_{uv}(k) = \text{Cov}(u_t, v_{t-k})$  represents the cross-covariance of  $u_t$  and  $v_t$  at lag  $k$ . The cospectrum  $Q_{uv}(\lambda)$  between two

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<sup>1</sup> The frequencies  $\lambda_1, \lambda_2, \dots, \lambda_N$  are specified as follows:

$$\lambda_1 = 2\pi / T$$

$$\lambda_2 = 4\pi / T .$$

The highest frequency considered is  $\lambda_N = 2N\pi / T$

where  $N \equiv T / 2$  if  $T$  is an even number and  $N \equiv (T - 1) / 2$  if  $T$  is an odd number (see Hamilton 1994, p.159).

series  $u_t$  and  $v_t$  at frequency  $\lambda$  can be interpreted as the covariance between the two series  $u_t$  and  $v_t$  that is attributable to cycles with frequency  $\lambda$ . The quadrature spectrum looks for evidence of out-of-phase cycles (see Hamilton 1994, p.274). The cross-spectrum can be estimated non-parametrically by

$$\hat{S}_{uv}(\lambda) = \frac{1}{2\pi} \left\{ \sum_{k=-M}^M w_k \hat{\gamma}_{uv}(k) e^{-i\lambda k} \right\} \quad (4)$$

with empirical cross-covariances  $\hat{\gamma}_{uv}(k) = \widehat{COV}(u_t, v_{t-k})$  and with window weights  $w_k$ , for  $k = -M, \dots, M$ . Equation (4) is called the weighted covariance estimator, and when the weights ( $w_k$ ) are selected as  $1 - |k|/M$  the Bartlett weighting scheme is obtained. The constant  $M$  denotes the maximum lag order considered. The spectra of Equations (1) and (2) are estimated in a similar way. This cross-spectrum allows us to compute the coefficient of coherence  $h_{uv}(\lambda)$ , defined as

$$h_{uv}(\lambda) = \frac{|S_{uv}(\lambda)|}{\sqrt{S_u(\lambda)S_v(\lambda)}} \quad (5)$$

The coefficient of coherence can be interpreted as the absolute value of a frequency-specific correlation coefficient, measuring the strength of the linear association between two time series. It takes values between 0 and 1. The squared coefficient of coherence has an interpretation similar to R-squared in a regression context. Lemmens et al. (2008) show that, under the null hypothesis that  $h_{uv}(\lambda) = 0$ , the estimated squared coefficient of coherence at frequency  $\lambda$ , with  $0 < \lambda < \pi$  when appropriately rescaled, converges to a chi-squared distribution with 2 degrees of freedom,<sup>2</sup> denoted by  $\chi_2^2$ .

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<sup>2</sup> For the endpoints  $\lambda = 0$  and  $\lambda = \pi$ , one only has 1 degree of freedom since the imaginary part of the spectral density estimates cancels out.

$$2(n-1)\hat{h}_{uv}^2(\lambda) \xrightarrow{d} \chi_2^2 \quad (6)$$

where  $\xrightarrow{d}$  stands for convergence in distribution, with  $n = T / (\sum_{k=-M}^M w_k^2)$ .

The null hypothesis  $h_{uv}(\lambda) = 0$  versus  $h_{uv}(\lambda) > 0$  is then rejected if

$$\hat{h}_{uv}(\lambda) > \sqrt{\frac{\chi_{2,1-\alpha}^2}{2(n-1)}} \quad (7)$$

with  $\chi_{2,1-\alpha}^2$  being the  $1-\alpha$  quantile of the chi-squared distribution with 2 degrees of freedom.

The coefficient of coherence in Equation (5) gives a measure of the strength of the linear association between two time series, frequency by frequency, but does not provide any information on the direction of the relationship between the two time series. Lemmens et al. (2008) decompose the cross-spectrum (Equation 3) into three parts: (i)  $S_{u \leftrightarrow v}$ , the instantaneous relationship between  $u_t$  and  $v_t$ ; (ii)  $S_{u \Rightarrow v}$ , the directional relationship between  $v_t$  and lagged values of  $u_t$ ; and (iii)  $S_{v \Rightarrow u}$ , the directional relationship between  $u_t$  and lagged values of  $v_t$ , i.e.,

$$\begin{aligned} S_{uv}(\lambda) &= [S_{u \leftrightarrow v} + S_{u \Rightarrow v} + S_{v \Rightarrow u}] \\ &= \frac{1}{2\pi} \left[ \gamma_{uv}(0) + \sum_{k=-\infty}^{-1} \gamma_{uv}(k) e^{-i\lambda k} + \sum_{k=1}^{\infty} \gamma_{uv}(k) e^{-i\lambda k} \right] \quad (8) \end{aligned}$$

The proposed spectral measure of GC is based on the key property that  $u_t$  does not Granger cause  $v_t$  if, and only if,  $\gamma_{uv}(k) = 0$  for all  $k < 0$ . The goal is to test the predictive content of  $u_t$  relative to  $v_t$ , which is given by the second part of Equation (8), i.e.,

$$S_{u \Rightarrow v}(\lambda) = \frac{1}{2\pi} \left[ \sum_{k=-\infty}^{-1} \gamma_{uv}(k) e^{-i\lambda k} \right] \quad (9)$$

The Granger coefficient of coherence is then given by

$$h_{u \Rightarrow v}(\lambda) = \frac{|S_{u \Rightarrow v}(\lambda)|}{\sqrt{S_u(\lambda)S_v(\lambda)}} \quad (10)$$

Therefore, in the absence of GC,  $h_{u \Rightarrow v}(\lambda) = 0$  for every  $\lambda$  in a  $[0, \Pi]$  interval. The Granger coefficient of coherence takes values between 0 and 1 (Pierce 1979). The Granger coefficient of coherence at frequency  $\lambda$  is estimated by

$$\hat{h}_{u \Rightarrow v}(\lambda) = \frac{|\hat{S}_{u \Rightarrow v}(\lambda)|}{\sqrt{\hat{S}_u(\lambda)\hat{S}_v(\lambda)}}, \quad (11)$$

with  $\hat{S}_{u \Rightarrow v}(\lambda)$  as in Equation (4), but with all weights  $w_k = 0$  for  $k \geq 0$ . The distribution of the estimator of the Granger coefficient of coherence is derived from the distribution of the coefficient of coherence Equation (6). Under the null hypothesis  $\hat{h}_{u \Rightarrow v}(\lambda) = 0$ , the distribution of the squared estimated Granger coefficient of coherence at frequency  $\lambda$ , with  $0 < \lambda < \pi$ , is given by

$$2(n'-1)\hat{h}_{uv}^2(\lambda) \xrightarrow{d} \chi_2^2 \quad (12)$$

where  $n$  is now replaced by  $n' = T / \left( \sum_{k=-M}^{-1} w_k^2 \right)$ . Since the  $w_k$  s, with a positive index  $k$ , are set equal to zero when computing  $\hat{S}_{u \Rightarrow v}(\lambda)$ , in effect only the  $w_k$  with negative indices are taken into account. The null hypothesis  $\hat{h}_{u \Rightarrow v}(\lambda) = 0$  versus  $\hat{h}_{u \Rightarrow v}(\lambda) > 0$  is then rejected if

$$\hat{h}_{u \Rightarrow v}(\lambda) > \sqrt{\frac{\chi_{2,1-\alpha}^2}{2(n'-1)}} \quad (13)$$

Afterwards, the Granger coefficient of coherence given by Equation (11) is calculated and tested for causality significance using Equation (13).

Using the above-mentioned methodology for India, first the casual relationships between the policy rate and inflation and the policy rate and output were explored, and then the causal relationship between the output gap and inflation, in order to suggest measures to achieve a balance between growth and inflation.

**6. EMPIRICAL ESTIMATION RESULTS AND THEIR ANALYSIS**

**6.1 Unit root tests**

Since stationarity of a series is a prerequisite for Granger causality analysis in both the time and the frequency domain, all the variables under study were tested for stationarity using the ADF test, PP test, and the Zivot-Andrews test. While the ADF and PP tests check for the level stationarity of a series, the Zivot-Andrews test checks for the unit root in the presence of a structural break in the series. The results of all these tests are discussed in Table 1 below. As shown in Table 1, all the variables are stationary in the level form. Both the ADF test and the PP test reject the null hypothesis of a unit root in the series at respective levels of significance. The IIP is found to be trend stationary. Similarly, the Zivot-Andrews test also rejects the null of a unit root for all the variables.

**Table 1:** Unit root tests

Variable	ADF test		PP test	Zivot-Andrews test
	Lag	Test statistic	Test statistic	Test statistic
Call rate	0	-3.787308***	-3.826917***	-5.3162**
CPI-IW inflation	6	-6.754681***	-10.13872***	-10.8389***
WPI inflation	0	-8.355354***	-8.355354***	-9.3877***
log (IIP)	5	-3.9025***	-22.97**	-9.0745***
Output gap	0	-12.77344***	-34.96737***	-12.7971***

**Note:** 1) ‘\*\*\*’, ‘\*\*’, and ‘\*’ denote statistical significance at 1%, 5%, and 10%, respectively. 2) Both the ADF and PP test include the constant term in the test equation for all variables, except for IIP, where constant and trend are included in the equation. 3) The Zivot-Andrews test was used for breaks in both the intercept and slope.

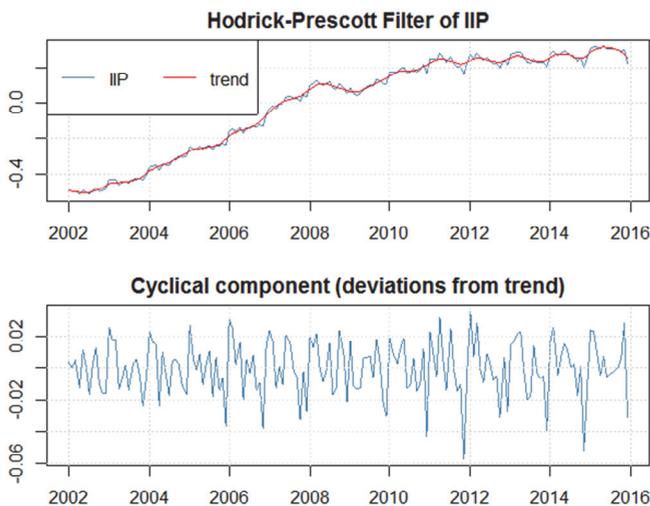
Since the data is of monthly frequency, it is necessary to look for possible seasonality. The present study uses the Beaulieu and Miron (1993) methodology to test for the seasonal unit roots in the log-transformed IIP, WPI, and CPI inflation series. Beaulieu and Miron (1993) extended the methodology developed by Hylleberg et al. (1990) to test for seasonal integration in monthly frequency data. The results of the seasonal unit root test show the absence of unit roots at both seasonal and non-seasonal frequencies. The results have not been reported here for brevity's sake. However, the possibility of deterministic seasonality in the series cannot be denied. Hence, to account for this, the IIP and inflation series were filtered using seasonal dummies.

### 6.2 Estimation of the relationship between output gap and inflation

The relationship between output gap and inflation provides necessary input for monetary policy decisions. The HP filter decomposes actual output into trend and cyclical components. The seasonally adjusted log IIP series was used to estimate the output gap.

The plot of the actual output along with potential output (trend) and output gap (cycles), as given by the HP filter, is depicted in Figure 5.

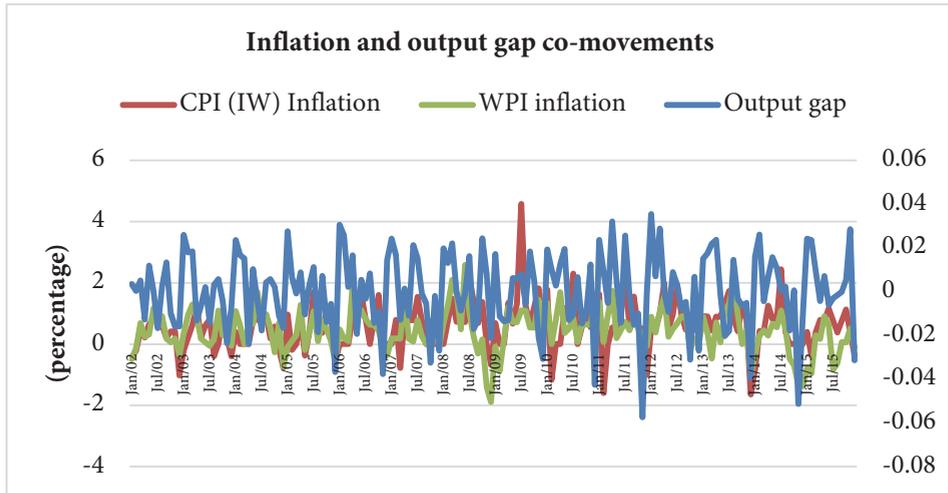
**Figure 5:** Actual output, output gap, and potential output



**Source:** the authors' calculation

Since output gap is considered to be one of the determinants of future inflation, the movements of the output gap have an implication for monetary policy formulation. Figure 6 shows output gap and inflation co-movements in India during the period January 2002 to December 2015.

**Figure 6:** Output gap and inflation co-movements



**Source:** the authors' calculation

As can be seen from the graph, output gap and inflation (CPI-IW and WPI) move in tandem, with a positive and lagged relationship between the two. The positive output gap, which indicates aggregate demand pressures in the economy, leads to an increase in inflation with a lag of around two to four months. Similarly, the negative output gap leads to a fall in inflation in the subsequent period with a lag.

**6.3 Granger Causality in the frequency domain**

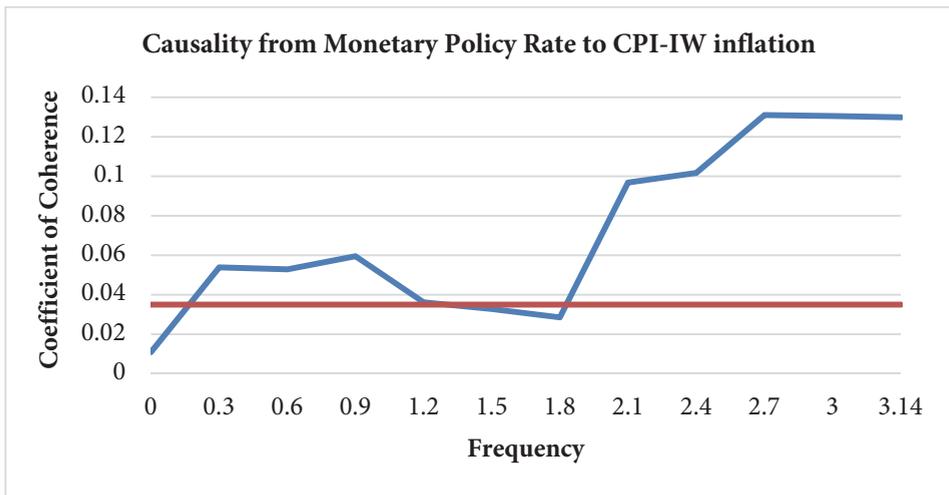
The results of the GC test in the frequency domain are discussed below with the help of the figures showing the coefficient of coherence between two series for all the frequencies. All the figures depict the test statistics along with their critical values at a 5% significance level (a line horizontal to the x-axis) for all frequencies in the interval (0,  $\Pi$ ). The horizontal axis represents the frequency ( $\omega$ ) in the fractions of  $\Pi$ . The frequency ( $\omega$ ) can be converted into time period (T) by applying the formula  $T=2\Pi/ \omega$ , where ‘T’ is the total time period (in this

study, months) and ‘ $\omega$ ’ is an angular frequency denoting a cycle per month, because the data is of monthly frequency. To interpret the results over the spectrum, all the frequencies are grouped into three frequency bands; i.e., short-run (range  $\omega \in [2-3.14]$ ), medium-run (range  $\omega \in [0.5-2]$ ), and long-run (range  $\omega \in [0.0-0.5]$ ). These three frequency bands correspond to the cycles of duration 2 to 3 months, 3 months to 12 months, and 12 months and beyond, respectively. These cycles with different time horizons replicate a true data-generating process for each series under study. The GC measures are shown in the Figures 7 to 14.

### 6.3.1. Causality between monetary policy rate and inflation

Figure 7 shows the causality running from monetary policy rate to CPI-IW inflation.

**Figure 7:** Causality from Monetary Policy Rate to CPI-IW Inflation



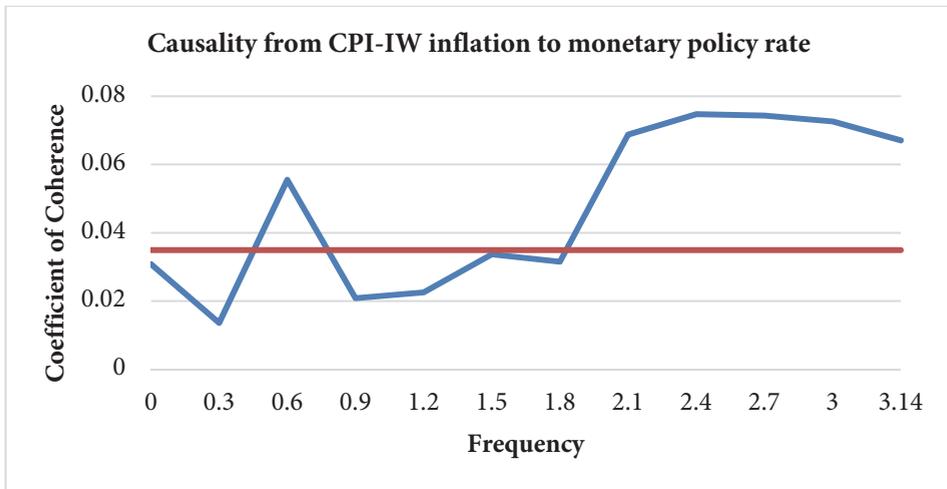
Source: the authors' calculation

As illustrated in Figure 7, the Granger coefficient of coherence indicating the causality running from policy rate to CPI-IW inflation is significant in the frequency range of  $\omega \in [0.3-1.2]$  and  $\omega \in [1.8-3.14]$ , corresponding to the cycles of 5 to 20 months and 2 to 3 months, respectively. The coefficient of coherence takes the maximum value of 0.13 at frequency 2.7, which corresponds to the cycle of 2 months. From the given frequency range it is very clear that monetary

policy only has a predictive power regarding retail inflation in the short-to-medium time horizon. Especially at all lower frequencies (below 0.3) the causality is insignificant, which, importantly, suggests that the link between monetary policy and retail inflation does not exist in the long-run. The magnitude of the causality also varies over the frequencies. The magnitude is high in the range of high frequencies (short time-horizon), which implies that monetary policy is more effective in influencing inflation in the short-run. However, such influence does not exist in the long-run. Even though monetary policy is more effective in the short-run the maximum value of the coefficient of coherence is as small as 0.13, which indicates the weak control of monetary policy over consumer inflation.

The reverse causality running from retail inflation to policy rate is significant in the frequency range of  $\omega \in [2-3.14]$ , corresponding to the cycles of 2 to 3 months. There is also evidence of significant causality in the medium-run frequencies  $\omega \in [0.5-0.8]$ . The magnitude of causality varies over the short- and medium-run frequencies.

**Figure 8:** Reverse causality from CPI-IW Inflation to Monetary Policy Rate



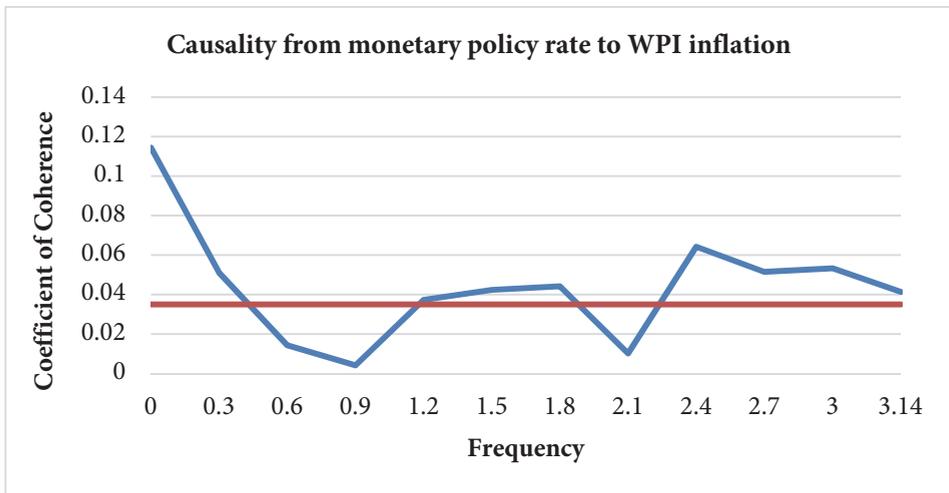
Source: the authors' calculation

The high magnitude of significant reverse causality from retail inflation to policy rate signifies that monetary policy is concerned about controlling inflation in the short-run.

To sum up the analysis of Granger causality, the study found evidence of a bi-directional causality between monetary policy rate and retail inflation. The bi-directional causality between the monetary policy impulses and retail inflation appears to be significant only in the short-to-medium-run. The significant reverse causality in the short-to-medium-run clearly highlights the fact that monetary policy in India is very sensitive to price fluctuations. The significant causal relationship that runs from the monetary policy impulses to retail inflation only over the short-to-medium-run signifies the inability of monetary policy to control retail inflation in the long-run in India. However, even though the causal relationship between monetary policy and retail inflation is significant in the short-run, the low magnitude of the coefficient of coherence (0.13) highlights monetary policy's weak control of inflation in India.

After investigating the impact of monetary policy on retail inflation, the next step in the analysis is to examine the impact of monetary policy on wholesale inflation as measured by the Wholesale Price Index (WPI).

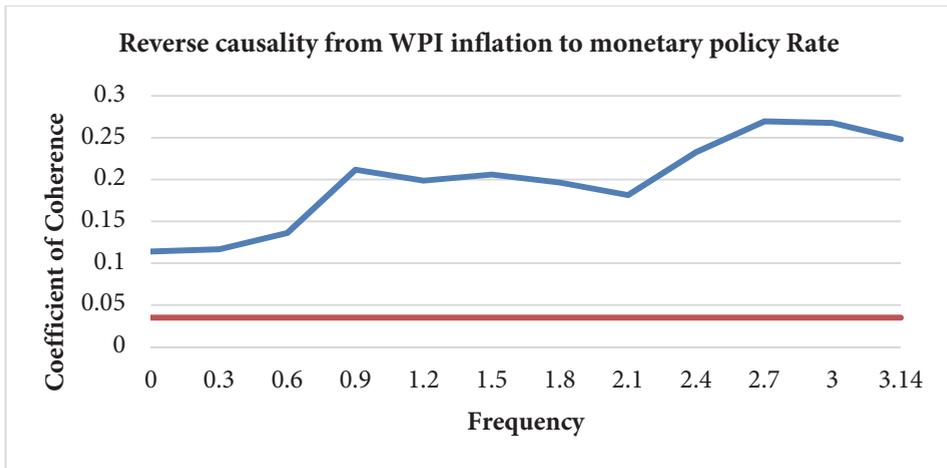
**Figure 9:** Causality from Monetary Policy Rate to WPI inflation



Source: the authors' calculation

As illustrated in Figure 9, the Granger coefficient of coherence indicating the causality running from monetary policy rate to WPI inflation is significant in the frequency range of  $\omega \in [0.0-0.5]$  and  $\omega \in [2.3-3.14]$ , corresponding to the cycles of 12 months and beyond and 2 to 3 months, respectively. The coefficient of coherence takes the maximum value of 0.12 at frequency 0, which corresponds to the long-run cycles. The evidence suggests that monetary policy has a predictive power regarding wholesale inflation in the short and long time-horizons. The causality seems to be absent in the medium-run frequencies, as there is no robust evidence of causality over those frequencies. The magnitude of the causality varies over the frequencies. However, the magnitude of causality is highest over the long-run frequencies (below 0.5), which signifies that monetary policy is more effective in impacting wholesale inflation in the long-run. However, such an impact does not exist in the medium-run. Even though monetary policy is more effective in the long-run, the maximum value of the coefficient of coherence is a meagre 0.12.

**Figure 10:** Reverse causality from WPI Inflation to Monetary Policy Rate



**Source:** the authors' calculation

The reverse causality running from wholesale inflation to policy rate is significant across all frequencies. However, the magnitude of the causality varies over different time horizons. The Granger coefficient of coherence takes the maximum value of 0.26 in the short-run frequency range and the minimum value of 0.11 in the long-run frequency range. The significant reverse causality

from wholesale inflation to monetary policy signifies that in India monetary policy is concerned about price stability.

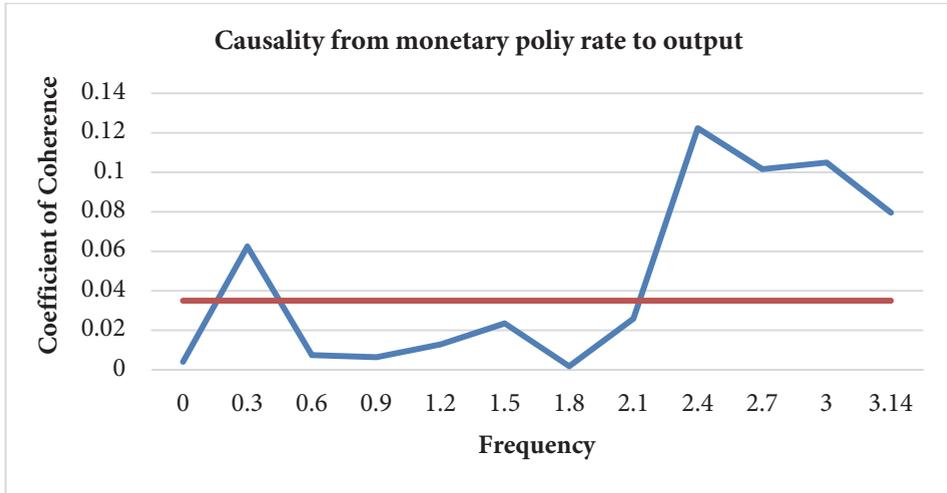
To sum up the analysis of Granger causality between monetary policy rate and wholesale inflation, the study found evidence of a bi-directional causality between policy rate and wholesale inflation. While the causality running from policy rate to WPI inflation appears to be significant in the short- and long-run frequencies, the reverse causality is significant across all time horizons. The highest magnitude of causality in the long-run denotes that the maximum impact of monetary policy on wholesale inflation is felt in the long-run. However, the low magnitude of the coefficient of coherence (0.12) highlights the weak control of monetary policy over inflation in India.

The comparison of the causality between monetary policy rate and retail inflation and monetary policy rate and wholesale inflation provides some important insights. In both cases the empirical evidence demonstrates a bi-directional causality. While the causality running from policy rate to retail inflation is significant in the short-to-medium-run, the causality running from policy rate to wholesale inflation is significant in the short- and long-run. The Granger coefficient of coherence takes the maximum value (0.13) in the short-run frequencies for the former, whereas it takes the maximum value (0.12) in the long-run frequencies for the latter. This suggests that monetary policy has the maximum impact on retail inflation in the short-run, whereas the maximum impact on wholesale inflation is felt in the long-run. There is a significant reverse causality from both retail and wholesale inflation to monetary policy rate, which implies that in India price stability is the prime concern of monetary policy.

### **6.3.2. Causality between monetary policy rate and output**

In the next step the study analyses the impact of monetary policy on output, as measured by the IIP. Figure 11 shows the Granger coefficient of coherence for monetary policy rate and output over different frequency bands.

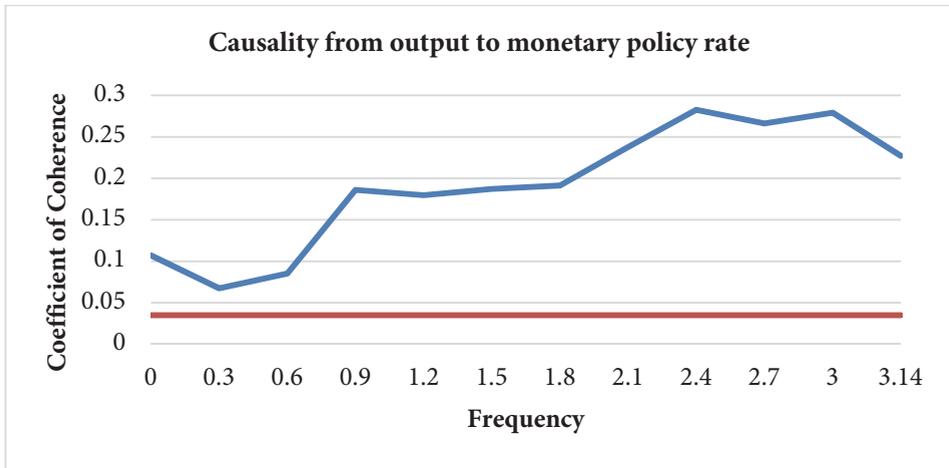
**Figure 11:** Causality from monetary policy rate to output



**Source:** the authors' calculation

The causality running from monetary policy rate to output is significant in the frequency range of  $\omega \in [0.2-0.5]$  and  $\omega \in [2-3.14]$ , corresponding to the cycles of 12 to 28 months and 2 to 3 months, respectively. However, the magnitude of causality is strong in the short-run  $\omega \in [2-3.14]$  and weak in the long run  $\omega \in [0.2-0.5]$ . The Granger coefficient of coherence takes the maximum value of 0.13 at frequency 2.4, corresponding to the cycle of 3 months. Similarly, it takes the minimum value of 0.06 over the long-run frequencies. The empirical evidence shows that a significant link between monetary policy and output prevails in India over the short and long time-horizons. However, monetary policy appears to have a strong impact on output only in the short-run, showing that monetary policy is most effective in the short-run. Since the causal link is strongest over the short-run frequencies corresponding to the cycles of 2 to 3 months, the impact of monetary policy is felt most in the short-run. Similarly, a relatively weak impact occurs over long-run frequencies corresponding to the cycles of more than 12 months. This means that in the long-run the intensity of the impact of monetary policy lessens.

**Figure 12:** Reverse causality from output to monetary policy rate



Source: the authors' calculation

The reverse causality going from output to policy rate is significant over all frequencies, indicating that the feedback from output to monetary policy is robust. However, the magnitude of the causality differs across the frequencies.

To sum up, the study finds evidence of a bi-directional causality running from monetary policy rate to output in India. The causality is found to be highly significant in the short-run frequencies. It denotes that the impact of monetary policy on output seems to be strongest in the short-run and weakest in the long-run. However, reverse Granger causality was found to be significant across all frequencies.

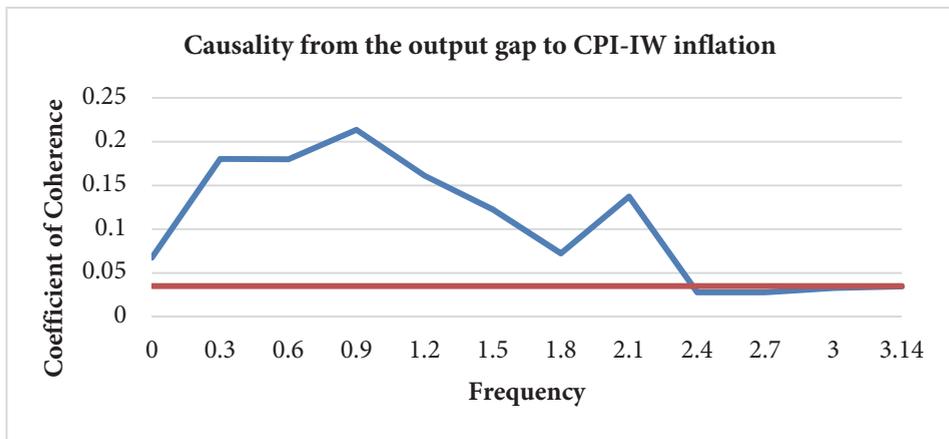
The results of the impact of monetary policy on output and inflation (both WPI and CPI) provide some interesting insights. The causality between policy rate and inflation and policy rate and output is found to be bi-directional. Importantly, this shows that in the recent past monetary policy decisions were being made on the basis of both inflation and output dynamics, as there is a significant reverse causality from both inflation and output to policy rate. The results show that output is almost as sensitive to monetary policy impulses as inflation because the magnitude of the coefficient of coherence is seen to be the same in both causalities (0.13). This provides some important insights. Since the Granger coefficient of coherence is the same for the causality from policy rate to

inflation (both CPI and WPI) and to output, any attempt to control inflation in the form of a tight monetary policy also ends up impacting output adversely, thereby hurting the growth process in India.

**6.3.3. Causality between output gap and inflation**

Since output gap is an indicator of future inflation, the next step in the analysis is to estimate the causality between output gap and inflation.

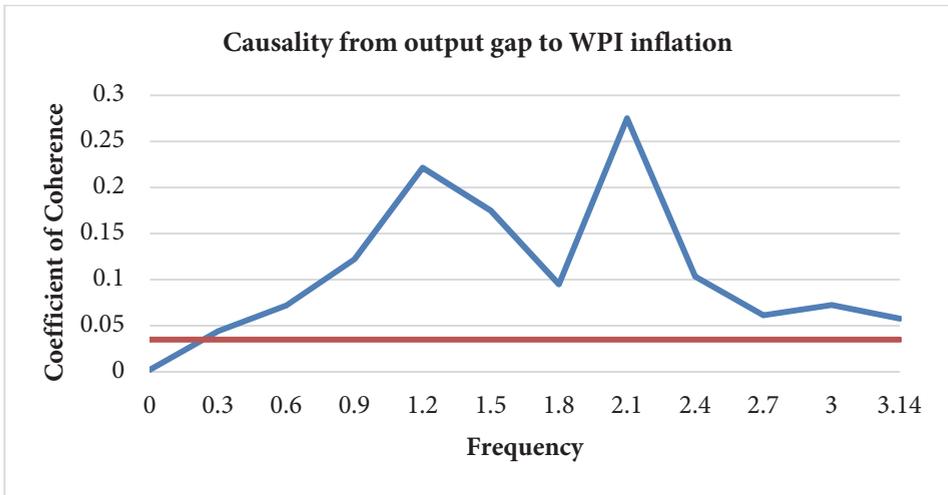
**Figure 13:** Causality from output gap to CPI-IW inflation



Source: the authors' calculation

Figure 13 shows the Granger coefficient of coherence for the causality running from output gap to CPI inflation. The graph shows that the output gap Granger causes inflation in the frequency band of  $\omega \in [0.0-2.4]$ , denoting short, medium, and long frequency cycles of three months and above. Also, the magnitude of the Granger coefficient of coherence varies over the given frequency range, with the highest magnitude of 0.21 occurring at medium-run frequency 0.9, corresponding to the cycle of 7 months. It can be concluded that output gap is a leading indicator of future inflation in India in the short-, medium-, and long-run. The evidence suggests a weak link between output gap and inflation in the long-run frequencies below 0.3, which is in line with the Phillips curve analysis.

**Figure 14:** Causality from output gap to wholesale inflation



**Source:** the authors' calculation

Figure 14 illustrates the causal relationship running from output gap to WPI inflation. The causality is significant in the frequency range of  $\omega \in [0.3-3.14]$ . Here, again, the magnitude of the coefficient of coherence varies across frequencies. It reaches its highest value of 0.27 at short-run frequency 2, corresponding to the cycle of 3 months. It can be seen that the link between output gap and inflation exists only in the short-to-medium-run, but not in the long-run, as causality over the long-run frequencies is insignificant.

To sum up, the causality running from output gap to CPI and WPI inflation suggests that a strong link between output gap and inflation exists over the short-to-medium range frequencies. There appears to be no or a weak link between the output gap and inflation in the long-run, which is in line with the Phillips curve relationship between output gap and inflation. Therefore the monetary authorities in India should take notice of the output gap and inflation relationship when setting policy rates, because output gap is one of the determinants of future inflation and could provide necessary input for policy formulation. The results discussed above (Figure 6) show a positive and lagged relationship between output gap and inflation in India. Also, the causality results indicate that the output gap Granger causes inflation only in the short-to-medium-run. Since current output gap determines current expectations of

future inflation, the current output gap could be an indicator of expected future inflation. Hence, monetary authorities striving to anchor inflation expectations could stabilise the output gap by adjusting the policy rate accordingly.

#### **6.4. Structural VAR analysis**

Granger causality analysis deciphers the predictive power of one variable vis-a-vis another, but fails to decode the underlying structural relationship between variables. The present study therefore uses the Structural Vector Auto-regression (SVAR) model to estimate the underlying structural relationship between the policy rate, inflation, and output growth on the one hand, and the output gap and inflation on the other.

The Vector Auto-Regression (VAR) methodology proposed by Sims (1980) has become a standard tool for monetary policy analysis. The standard (reduced form) VAR models explain the endogenous variables by their own past values, and deterministic regressors. In such model specifications the instantaneous relationships between variables are not accounted for and therefore are hidden in the variance-covariance matrix of the model error terms. These VAR models therefore are atheoretical in nature and there is little economic interpretation of their results. By contrast, the SVAR models allow researchers to use economic theory to transform the reduced-form VAR models into a system of structural equations. These models then allow the explicit modelling of contemporaneous relationships between the endogenous variables in a structural theoretical sense, and provide explicit behavioural interpretation of the model parameters.

The parameters of the transformed models are then estimated by imposing contemporaneous identifying restrictions that must be motivated by economic theory, institutional knowledge, and other extraneous constraints on the model responses. Only after decomposing the forecast errors into structural shocks that are mutually uncorrelated and have economic interpretation can we assess the causal effects of these shocks on the endogenous variables. The SVAR models therefore yield impulse responses that can be given structural interpretation.

Within the SVAR framework, a reduced-form model is estimated, which is approximated by a VAR specification of the form

$$y_t = C + A_1 y_{t-1} + A_2 y_{t-2} + \dots + A_p y_{t-p} + e_t$$

where  $y_t$  is the vector of  $n$  endogenous variables,  $C$  is the vector of constants,  $e_t$  is the vector of residuals of the VAR process, and  $P$  is the number of lags included. Also,  $A_1$  to  $A_p$  are  $n \times n$  coefficient matrices of lagged endogenous variables.

Once the reduced-form VAR model is estimated, the next task is to estimate the SVAR model by decomposing the residuals of the standard VAR into structural shocks. This corresponds to finding instantaneous relationships between structural and reduced-form innovations, in the form of

$$e_t = B \varepsilon_t$$

where  $e_t$  stands for the vector of estimated VAR residuals and  $\varepsilon_t$  is the vector of structural shocks. It is assumed that the structural shocks are orthogonal to each other, which may not be true for the VAR residuals. Matrix  $B$  consists of coefficients denoting the instantaneous impact of the structural shocks on the endogenous variables. In order to identify the matrix  $B$ ,  $n(n-1)/2$  additional restrictions have to be imposed on this matrix to attain exact identification. The present study uses the point zero restriction approach (Khundrakpam and Jain 2012) to identify the  $B$  matrix. This approach restricts some of the elements of the  $B$  matrix to zero.

The present study estimates the SVAR model consisting of output growth (proxied by IIP growth), inflation (CPI and WPI), and the policy rate (proxied by call rate) as endogenous variables.<sup>3</sup> Since CPI and WPI inflation may respond differently to policy shocks, the present study estimates the SVAR model for CPI and WPI inflation separately. Also, to understand the dynamics of output gap and inflation the model is re-estimated using the output gap variable instead of the output growth rate in one of the model specifications. However, the restrictions imposed in the  $B$  matrix remain the same throughout different specifications of the model.

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<sup>3</sup> All the variables are stationary and seasonally adjusted, except the call rate.

The SVAR model with point zero restrictions is as follows:

$$\begin{bmatrix} e_{1t}^{Output} \\ e_{2t}^{Inflation} \\ e_{3t}^{Call} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ a_{21} & 1 & 0 \\ a_{31} & a_{32} & 1 \end{bmatrix} \begin{bmatrix} \varepsilon_{1t}^{Output} \\ \varepsilon_{2t}^{Inflation} \\ \varepsilon_{3t}^{Call} \end{bmatrix}$$

where  $e_i$  stands for the VAR residuals and  $\varepsilon_i$  denotes the structural shocks. Since the present study primarily analyses the impact of monetary policy on output and inflation in India, the restrictions imposed in the B matrix are based on the theory of Indian monetary policy transmission. It is evident from the existing literature that the policy rate (call rate) affects output growth and inflation only with a lag. However, the policy rate is allowed to respond contemporaneously to the shocks in output growth and inflation. Hence, the zero restrictions in the first row of the B matrix denote that the output growth does not respond contemporaneously to the shocks in inflation and the policy rate. It implies that the shocks to the output growth are exogenous. Similarly, the second and third rows correspond to the equations for inflation and the policy rate respectively. The inflation equation implies that the inflation responds contemporaneously to shocks in the output growth only.<sup>4</sup> Finally, the third equation implies that the policy rate responds contemporaneously to shocks in both output growth and inflation.

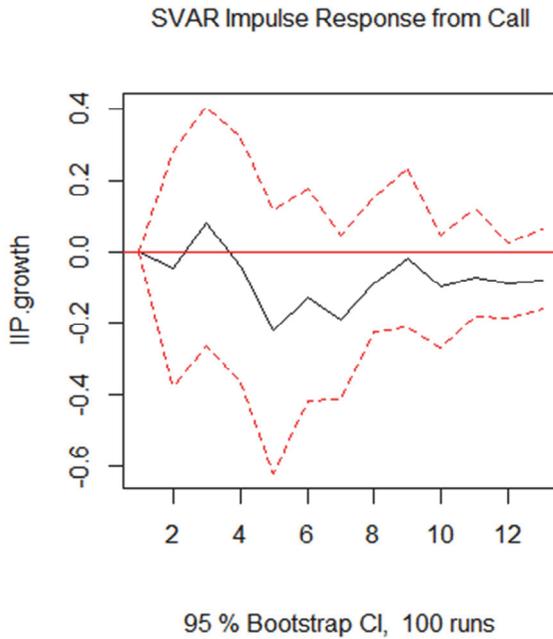
#### 6.4.1. Empirical results of the SVAR model

Since the aim of the present study is to explore the impact of monetary policy shocks on output and inflation in India, the figures given below depict the impulse responses of output growth and inflation to policy shocks.<sup>5</sup> The impulse responses of inflation to output gap shocks are also provided.

<sup>4</sup> This equation is based on the time domain causality analysis that shows uni-directional causality from output growth to inflation.

<sup>5</sup> Due to lack of space, remaining impulse responses are not provided here but are available on request.

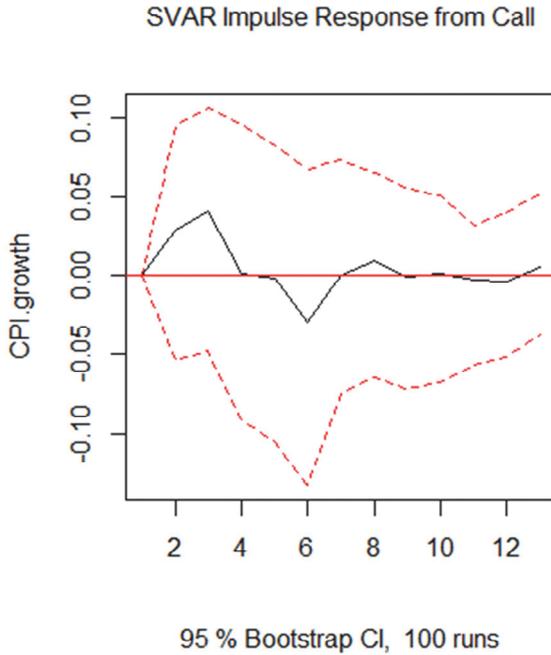
**Figure 15:** Impulse response function of policy rate on output growth



**Source:** the authors' calculation

The impulse response function shows that an increase in the policy rate leads to a fall in output growth below the baseline after four months. The maximum fall in the output growth occurs in the fifth month. Thereafter, the impact on growth decays slowly, with the overall impact persisting more than 7 to 8 months ahead.

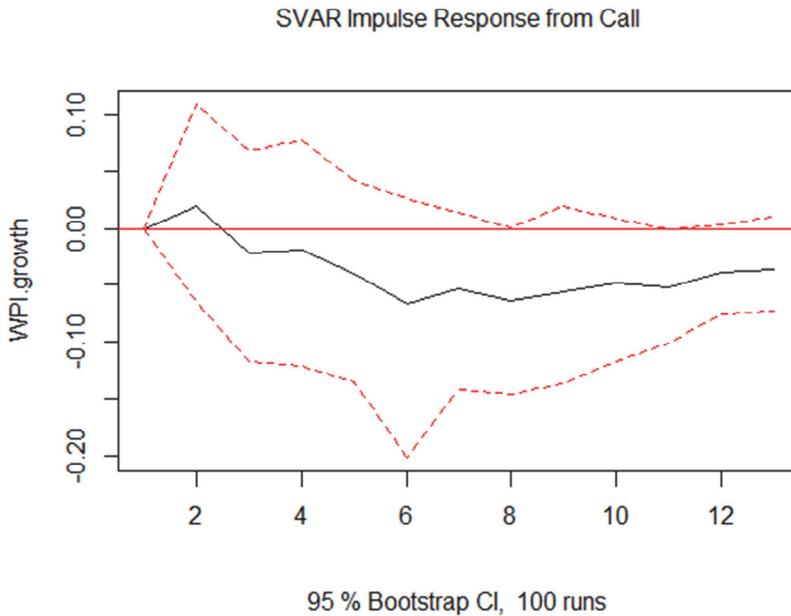
**Figure 16:** Impulse response functions of policy rate on CPI inflation



**Source:** the authors' calculation

The impact of monetary policy shock on inflation occurs with some lags after the output growth. CPI inflation starts falling only after the fifth month and the maximum impact is felt in the sixth month. The overall decline in CPI inflation continues 2 to 3 months ahead.

**Figure 17:** Impulse response functions of policy rate on WPI inflation



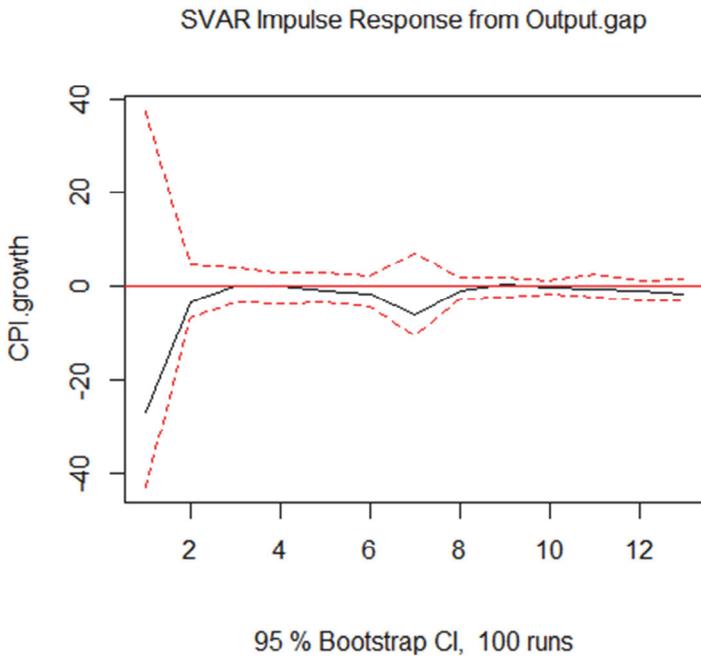
**Source:** the authors' calculation

The response of WPI inflation to monetary policy shock differs from that of CPI inflation. The increase in policy rate leads to a fall in WPI inflation after four months, with the maximum fall occurring in sixth months. However, the fall in WPI inflation continues for more than six months ahead. It is WPI inflation that starts falling first after the policy shock, and then CPI inflation follows. Also, the fall in CPI inflation is short-lived and of a lower magnitude than the WPI inflation. It seems that the WPI inflation responds more to the policy shock than CPI inflation. That could be because the Reserve Bank of India used WPI measure of inflation during most of the sample period.

The impulse response function analysis of monetary policy shock on output growth and inflation corroborates the initial findings of the causality analysis. The monetary policy in India has a significant impact on output and inflation in the short-to-medium-run. After the policy shock, the fall in the output growth

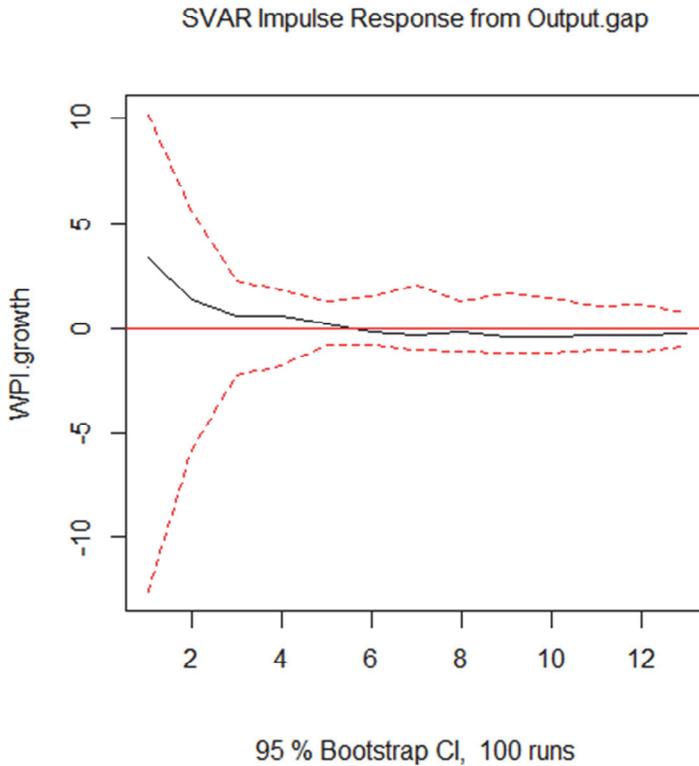
rate is of greater magnitude than the fall in inflation. Hence, attempts to control inflation by pursuing tight monetary policy hurt the growth process in India.

**Figure 18:** Impulse response functions of output gap on CPI inflation



**Source:** the authors' calculation

**Figure 19:** Impulse response functions of output gap on WPI inflation



**Source:** the authors' calculation

The shock to the output gap (widening of the output gap) leads to a fall in inflation (both CPI and WPI) after six months. The peak impact is felt in the seventh month. The fall in inflation persists for several months ahead. These findings support the evidence from the causality analysis of a strong link between the output gap and inflation in the short-to-medium-run.

## **7. POLICY IMPLICATIONS AND CONCLUSION**

This study uses the frequency domain causality approach developed by Lemmens et al. (2008) to analyse the causal relationship between monetary policy rate and inflation, and monetary policy rate and output in India. The

study finds a bi-directional causality between policy rate and inflation. In the same way, the evidence shows bi-directional causality between policy rate and output. This implies that the Indian monetary authorities were equally concerned about inflation and growth when deciding policy. The impulse response function analysis from the estimated SVAR signifies that the negative impact of policy rate on output growth is of greater magnitude than its impact on inflation. Hence, the tight monetary policy pursued in the recent past to control inflation increasingly impacted output at the same time, thereby hurting the growth process. As the Reserve Bank of India implements an inflation-targeting framework, it is essential to note that output growth should not take a hit in an attempt to control inflation: it is necessary to strike a fine balance between the two. To provide an in-depth analysis of the relationship between policy rate and inflation, this study explores the causal relationship using both retail and wholesale inflation, separately. While the causality running from policy rate to CPI inflation is significant over the short-to-medium-run frequencies, the causality running from the policy rate to WPI inflation is significant over the short and long frequency range. The output gap and inflation relationship could provide essential inputs for controlling inflation. The present study therefore analyses causality running from output gap to both CPI and WPI inflation in India. The output gap and inflation relationship was found to be positive, as reported in earlier studies. It was found that the output gap Granger causes inflation only in the short-to-medium-run frequencies. The impulse response of inflation to output gap shock also implies that inflation falls after a lag, and the maximum impact is felt in the seventh month. The monetary authorities striving to control inflation in the short-to-medium-run should see the current output gap as one of the determinants of expected future inflation and should shape policy accordingly in order to anchor inflation expectations.

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