IMPACT OF FOOD INFLATION ON HEADLINE INFLATION IN INDIA

*Anuradha Patnaik**

A commonly held belief in the 1970s was that price indices rise because of temporary noise, and then revert after a short interval (Cecchetti and Moessner, 2008). Accordingly, policy should not respond to the inflation because of these volatile components of the price indices. This led to the development of the concept of core inflation (Gordon, 1975), which is headline inflation excluding food and fuel inflation. It was strongly believed that in the long run, headline inflation converges to core inflation and that there are no second round effects (that is an absence of core inflation converging to headline inflation). In recent years, however, major fluctuations in food inflation have occurred. This has become a major problem in developing countries, such as India, where a large portion of the consumption basket of the people are food items. Against this backdrop, in the present paper, an attempt is made to measure the second round effects stemming from food inflation in India using the measure of Granger causality in the frequency domain of Lemmens, Croux and Dekimpe (2008). The results of empirical analysis show significant causality running from headline inflation to core inflation in India and as a result, the prevalence of the second round effects. They also show that food inflation in India is not volatile, and that it feeds into the expected inflation of the households, causing the second round effects. This calls for the Reserve Bank of India to put greater effort in anchoring inflation expectations through effective communication and greater credibility.

JEL classification: E31, E50

Keywords: core inflation, monetary policy, food inflation, second round effects, inflation expectations

* Anuradha Patnaik, PhD, Associate Professor, Mumbai School of Economics and Public Policy, University of Mumbai, India (email: Dr.A.Patnaik75@gmail.com).

I. INTRODUCTION

A commonly held belief in the 1970s was that price indices rise because of temporary noise, resulting from volatile food or fuel prices, and then reverted after a short interval (Cecchetti and Moessner, 2008). This led to the development of the concept of core inflation or baseline inflation (Gordon, 1975), which is primarily defined as the aggregate inflation or the headline inflation excluding the food and fuel inflation (Eckstein, 1981; Blinder, 1982; Thornton, 2007; Wynne, 2008; among others). The emphasis on core inflation was motivated by the fact that historically food and fuel inflation have been correcting themselves in the short run. This means that there are no second round effects of food and fuel inflation such that a disruption in the headline inflation caused by food inflation dies out in the short run, and the core inflation remains unaffected. As a result, headline inflation is expected to eventually converge to the core inflation or the underlying trend inflation (Clark, 2001) and that policy should not respond to the inflation because of the volatile components of the price indices. It is important to note that a "core measure of inflation is not an end in itself, but rather a means to achieve low and stable inflation by serving as a short-term operational guide for monetary policy" (Raj and Misra, 2011). Many economists also believe that as core inflation is a measure of the underlying trend in inflation, it may also be important in projecting inflation (Freeman, 1998; Goyal and Pujari, 2005).

Contrary to the above viewpoint, however, research in recent years has indicated that in low-income countries where food comprises a major portion of the consumption basket, food prices have become more steadfast. Similar problems were apparent even in developed countries following the rise in food prices over the period 2003-2007, during which food price shocks were transmitted into the non-food prices also as a result of the beginning of the breakdown of the relationship between core inflation and headline inflation (Walsh, 2010). Both started to diverge, implying that the so-called volatile component, food inflation, is no longer volatile. This not only obstructed the smooth functioning of monetary policy, but it also resulted in distortions in inflation forecasts of central banks and consequently, the inflation expectations. Needless to mention, it is essential that monetary policy should be aimed at preventing the second round effects of higher food prices on inflation expectations and wages, and thereby control future inflation (Cecchetti and Moessner, 2008). Alternatively, if monetary policy is unsuccessful in blocking the second round effects because of food inflation, the expectations of future inflation by households and firms would be underestimates or overestimates of future inflation. This would create a wedge between the actual inflation and expected inflation and eventually lead to ineffective inflation targeting and loss of credibility of the central bank.

The above analysis is extremely relevant in the case of India where the weight of food items taken together is 47.51 in the consumer price index combined (CPI-C, hereafter), which is the official measure of inflation. The significance of the issue is

amplified further as monetary policy in India has been altered by adopting flexible inflation targeting as the new monetary framework. Under the inflation targeting framework, the Reserve Bank of India must be forward looking and able to predict future inflation accurately so as to achieve the targeted inflation by aligning the inflation expectation to its projected inflation rate. When a central bank, such as the Reserve Bank of India, communicates the future inflation forecast to the public, expectations are formed based on these inflation forecasts only if the institution is credible. A central bank earns credibility over a period of time if the projected inflation is close to the actual inflation. Thus, the success of inflation targeting lies in how accurately central bank forecasts future inflation (Blinder, 1999). Central banks use relevant models to forecast future inflation (Benes and others, 2016), which usually do not incorporate the second round effects of component inflation measures. As a result, the projected inflation does not coincide with the actual inflation (figure 9, section III); this becomes detrimental for the central bank, which loses its credibility in the long run and the inflation targeting framework eventually collapses. As this phenomenon of the second round effects of food inflation has serious policy implications in terms of formulating expectations in line with the prediction of future inflation, the objective of the present study is to explore empirically, in the frequency domain, the second round effects of food inflation, and then the changing dynamics between the headline and core inflation because of persistent food inflation in India. The rest of the paper is organized as follows: section II contains a review of the literature. The definitional aspects of the inflation measures used, and the trends in inflation are discussed in section III. The methodological details and data used are discussed in section IV. The results of empirical analysis are reported in section V. Finally, section VI includes a discussion of the results and concludes.

II. REVIEW OF THE LITERATURE

The concept of core inflation was developed in the 1970s when the Organization of Petroleum Exporting Countries (OPEC) was at its height; it was realized that the underlying trend in inflation had to be tracked for policy purposes, rather than the headline or aggregate inflation. Since then, several studies on the relevance of core inflation have been conducted. Among them are the following: Sprinkel (1975); Tobin (1981); Eckstein (1981); Blinder (1982); Rich and Sendel (2005). The authors of these studies are among the pioneers to propose that measured inflation can be split into three parts: the core inflation; the demand inflation; and the shock inflation.

Since then, headline inflation is constructed by assigning different weights, for the commodities entering the consumer price index/wholesale price index (CPI/WPI) basket, which also includes food and fuel prices, and deriving the core inflation from the headline inflation has become a matter of extensive research. Clark (2001) compared five different measures of core inflation. Of the five measures, three measures (CPI excluding food and energy, trimmed mean, and median CPI) were previously developed,

and the other two (CPI excluding energy, and CPI excluding eight components) were developed by Clark. The study showed that the trimmed mean and CPI excluding fuel were the superior measures of core inflation. While giving a detailed account of the different measures of core inflation used by different central banks, Shiratsuka (2006) tried to identify the core inflation for Japan by capturing the nature and size of idiosyncratic disturbances behind CPI of Japan. A review of various approaches to measure core inflation can be found in Wynne (2008), who linked these approaches in a single theoretical framework called the stochastic approach to index numbers. He concluded by saying that the different measures lack a well-formed theory of what these measures of inflation need to capture. Similar research using the stochastic approach was also conducted by Clements and Izan (1981; 1987), Bryan and Pike (1991), and Bryan and Cecchetti (1993; 1994).

In the past decade, recurrent and persistent spikes in food prices were experienced globally (Bhattacharya and Gupta, 2015), resulting in questioning the validity of core inflation as the short-term guide for monetary policy. Many studies, such as Thornton (2007), Walsh (2010), and Cecchetti and Moessner (2008), dealt with the issue of whether core inflation can predict future headline inflation. While Cecchetti and Moessner (2008) concluded that in a majority of the countries considered by them, headline inflation converged to core inflation. Other studies, however, concluded that whether headline inflation converges to core inflation depends on the measure of core inflation. As Thornton (2007) explains, “alternative is to consider different measures of ‘core’ inflation and not rely on the measures that exclude simply food and energy prices”.

Similar studies related to India are also available in which the average food inflation was the highest among the emerging market economics during the period 2006-2014 (Bhattacharya and Gupta, 2015). Literature on food inflation in India and its causes can be found in, among others, the works of Nair and Eapen (2012), Guha and Tripathi (2014), Bhattacharya and Gupta (2015). Estimation of the second round effects of the food inflation, using different variants of the core inflation of India are available in research conducted by Raj and Misra (2011), who attempted to analyse seven exclusion-based measures of core inflation for India with regard to volatility, persistence and predictive power for headline inflation, using time-series techniques. The study indicated that there were the second round effects in six out of the seven measures of core inflation considered. It was, therefore, concluded that headline inflation, not core inflation, should be the focus of monetary policy in countries such as India where food and fuel comprise a major portion of the consumer basket. Bhattacharya and Gupta (2015) analysed the causes and determinants of food inflation in India using time-series tools. Significant pass through effects from food to non-food inflation was found, clearly implying the presence of the second round effects. Anand, Ding and Tulin (2014) estimated the second round effects using reduced form general equilibrium models. They clearly showed the presence of the strong second round effects. Goyal and Baikar

(2015) concluded that the causality from headline inflation to core inflation occurred only when the food inflation crosses double digits. Dholakia and Kadiyala (2018) concluded that the second round effects were weak in the case of India beginning in 2012. It can be seen that many researchers have attempted to estimate the second round effects of food inflation on core inflation and have arrived at different conclusions.

"There is an ongoing debate on the direction of convergence between headline inflation and core inflation and its probable impact on future course of monetary policy" (Goyal and Parab, 2019, p.1). Inflation targeting framework requires the central bank to be able to forecast the future inflation rates accurately (Blinder, 1999). Central banks set their inflation target by announcing the projected inflation rate for the next quarter. The projected inflation rate is then taken by the firms as the expected future inflation rate for price and wage setting for the next time period, and by households for their consumption and savings decisions (Goyal and Parab, 2019), only if the central bank is credible. Thus, the central bank anchors inflation expectations through its inflation forecast and the expected inflation, and holds the key to the success of inflation targeting by aborting the second round effects of transitory shocks that could lead to persistent inflation (Goyal and Parab, 2019). Against this backdrop, in many studies, there have been attempts to explore if the core inflation can be used to forecast the headline inflation correctly in the presence of high food inflation (Thornton, 2007; Walsh, 2010; Cecchetti and Moessner, 2008). Misati and Munene (2015) estimated the second round effects of food inflation on non-food inflation of Kenya and stressed the importance of communication there by anchoring inflation expectations in order to mitigate the impact of the second round effects on actual inflation. Thus, second round effects of food shock affect the inflation forecast through the inflation expectations of households and firms. As a result, accurate knowledge of the second round effects is very crucial to being able to forecast inflation accurately.

The review of literature highlights the crucial importance of the knowledge of the second round of food shocks (or any transitory shock) for the success of inflation targeting monetary policy. Though a number of studies have been conducted on the second round effects of food shocks for India in the time domain, in the present paper the second round effects of food inflation, food inflation causing headline inflation, and headline inflation causing core inflation are revisited in the frequency domain using the methodology of Lemmens, Croux and Dekimpe (2008). The novelty and relevance of the present study is that the magnitude of causality and the time taken for transmission of shocks from food inflation to headline and core inflation will also be derived. To the best of the author's knowledge, similar studies in the frequency domain, under Indian conditions have not been carried out. An attempt is also made to measure the responsiveness of the inflation measures to monetary policy. These results throw light on the crucial importance of communication by the central bank in the success of monetary policy in an inflation targeting framework.

III. INFLATION: DATA SOURCES, DEFINITIONS AND TRENDS

Variables used and database

The variables used in the empirical analysis in section V are as follows:

(a) Monthly headline inflation measured as the year-on-year growth in the consumer price index combined, CPI-C, sourced from the Ministry of Statistics and Programme Implementation website, for the period January 2012 – June 2019.

(b) Monthly core inflation measured as the year-on-year growth in CPI-C (core), estimated from CPI-C data using equation 1, for the period January 2012 – June 2019 (details given in the next section on Definitions).

(c) Food inflation measured as the year-on-year growth in the CPI-C (food), sourced from the Ministry of Statistics and Programme Implementation website, for the period January 2012 – June 2019.

(d) Weighted monthly average call money rate (proxy for repo rate), sourced from the Reserve Bank of India *Handbook of Statistics on Indian Economy*, for the period January 2012 – June 2019.

(e) Inflations expectation of households, sourced from the Reserve Bank of India, Inflation Expectations Survey of Households, June 2019.

A brief note on the variables used

The consumer price index combined (CPI-C) has been adopted as the official measure of inflation by the Reserve Bank of India, as per the recommendations of the Expert Committee to Revise and Strengthen the Monetary Policy Framework (Reserve Bank of India, 2014). The Ministry of Statistics and Programme Implementation publishes monthly figures of CPI-C and its components (for details see table 1). The CPI measures change over time in the general level of prices of goods and services acquired by the households for consumption, and is therefore used to represent the retail price index of the country. The monthly price data for the items included in the CPI consumption basket are collected from 1,114 markets in 310 selected towns and 1,181 selected villages by the National Sample Survey of India and the Department of Posts, respectively, through web portals and then three indices, CPI-Rural, CPI-Urban, and CPI-C are calculated and published by the Ministry of Statistics and Programme Implementation. As CPI-C is the official measure of inflation in India for the present study, it is also the measure of inflation for the empirical analysis. The broad components and their respective weights in CPI-C, CPI-Rural and CPI-Urban are reported in table 1. It is interesting to note that food and beverages are assigned the highest weight in each of the price indices. This is followed by the miscellaneous item. The weights are constantly changing with respect to the base year used.

Table 1. Components and their weights in the CPI-C, CPI-Rural and CPI-Urban (base year, 2012)

Component/item	Weight in CPI-Rural	Weight in CPI-Urban	Weight in CPI-C
Food and beverages	54.18	36.29	45.49
Pan, tobacco and intoxicants	3.26	1.36	2.02
Fuel and light	7.49	5.58	6.84
Housing	–	21.67	21.67
Clothing	7.36	5.57	6.28
Miscellaneous	27.26	29.53	28.31

Source: India, Ministry of Statistics and Programme Implementation. Available at www.mospi.gov.in/.

The repo rate is the official instrument used for conducting monetary policy by the Reserve Bank of India. For empirical purposes, however, the repo rate is very difficult to handle (does not become stationary easily). Accordingly, the weighted average monthly call money rate, which is the operating instrument of monetary policy of India and is closely aligned with the repo rate has been used as a proxy for monetary policy in India.

Definitions

The present study

Changes in CPI-C for all commodities are treated as the headline inflation for policy articulation, and within CPI-C, the "non-food items" inflation is considered the core inflation in India (Mohanty, 2011). This implies that when prices of food and beverages, pan, tobacco and intoxicants and fuel and power prices are excluded from CPI-C, the results in the prices of core items in CPI-C are attained. The core inflation represents the underlying trend of inflation as shaped by the pressure of aggregate demand against the existing capacity. The non-core part of the headline inflation constitutes the food inflation, and is usually considered to reflect the price movements caused by temporary shocks or relative price changes (Laflèche and Armour, 2006). It is important to note that the Ministry of Statistics and Programme Implementation also publishes the food price index data for CPI-C; however, the core price index is not readily available. Consequently, for the present study, the exclusion-based measure, as suggested by Bhattacharya and Gupta (2015), is used to estimate the core inflation as given in equation 1 below. The exclusion based core price index can be derived from CPI-C as follows:

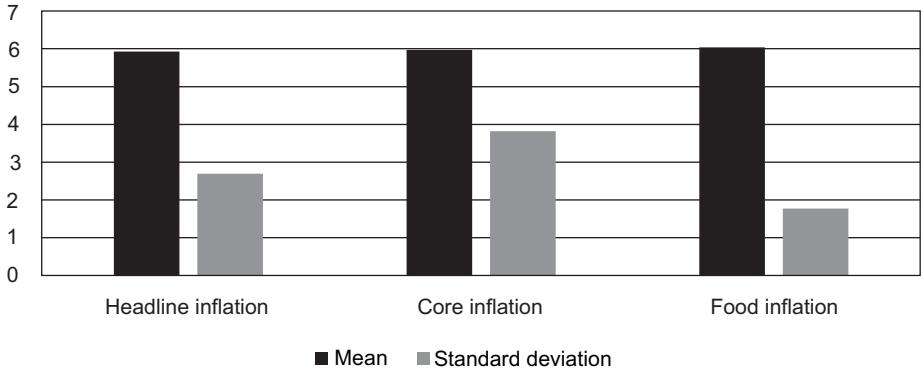
$$core\ price\ index = \frac{CPIC - w(fa)CPIC(fa) - w(fp)CPIC(fp) - w(fu)CPIC(fu)}{1 - w(fa) - w(fp) - w(fu)} \quad (1)$$

Where, w(fa) is weight of food and beverages in CPI-C, w(fp) is weight of pan, tobacco and intoxicants in CPI-C, w(fu) is weight of fuel and light in CPI-C, and CPIC is CPI combined.

For the present study, the headline inflation is measured as the year-on-year difference in CPI-C; food inflation is measured as the year-on-year difference in the CPI-food price index, and the core inflation is derived as the year-on-year difference in the core price index derived from equation 1 above. Because of the year-on-year differencing of the price data to deriving the inflation data, 12 observations were lost from the original sample of 102 observations and the sample size was reduced to 90 observations.

The trends in inflation

Figure 1. Mean and standard deviation of headline, core and food inflation (measured as the year-on-year growth rate of the respectve CPI combined measures) for the period January 2012 – June 2019

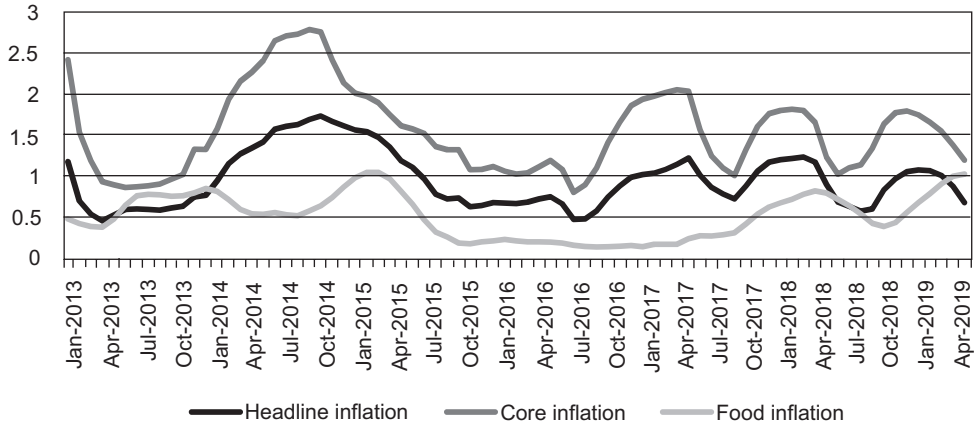


Source: Author's own calculations using CPI-C data derived from the Ministry of Statistics and Programme Implementation. Available at www.mospi.gov.in/.

Figure 1 depicts the behaviour of the mean and standard deviation of the headline, core and food inflation rates for January 2012 to June 2019. It can be clearly seen that while the mean values of each of the inflation measures for the period is approximately 6 per cent (5.93 headline inflation, 5.96 core inflation and 6.03 food inflation), the standard deviation varies across the three measures. It can be used to measure the long-term volatility in a particular time series such that the higher the standard deviation the higher the long-term volatility. It is interesting to note that while food inflation is normally considered to be the most volatile component, its volatility as measured by the standard deviation is the least at 1.7675, followed by headline inflation, at 2.69, in the

present sample. Core inflation is usually not considered to be volatile; however, in the present case it emerges as the most volatile measure of inflation with a standard deviation of 3.81. The 12-month rolling standard deviations of the three inflation measures also depict a similar picture. As indicated in figure 2, the 12-month rolling standard deviation of core inflation is more than the 12-month rolling standard deviation of the headline inflation and the food inflation for the entire time period, December 2012 to June 2019. It is also interesting to note that the rolling standard deviation of food inflation appears to be the least volatile component with the lowest standard deviation throughout the rolling window.

Figure 2. Twelve-month rolling standard deviation of headline, core and food inflation rates (January 2012 to June 2019)

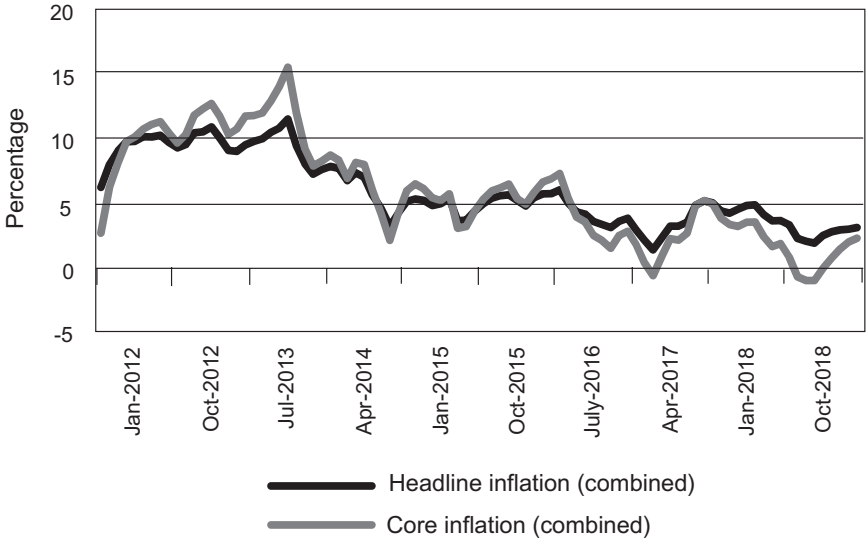


Source: Author's own calculations using CPI-C data derived from the Ministry of Statistics and Programme Implementation. Available at www.mospi.gov.in/.

Ideally, the mean of the headline inflation should be around the mean of core inflation, but the standard deviation of the core inflation should be lower than the standard deviation of the headline inflation (Reserve Bank of India, 2019). Accordingly, it can be concluded that the core inflation appears to be the most volatile component of headline inflation from the preliminary analysis.

From figure 3, it can be observed that the headline inflation and the core inflation are more or less moving together. For a major part of the study sample, the core inflation appears to be higher than the headline inflation. Post-November 2017, however, the core inflation fell below the headline inflation. Figures 4 and 5 clearly show that the food inflation does not meander either with the headline inflation or the core inflation. It

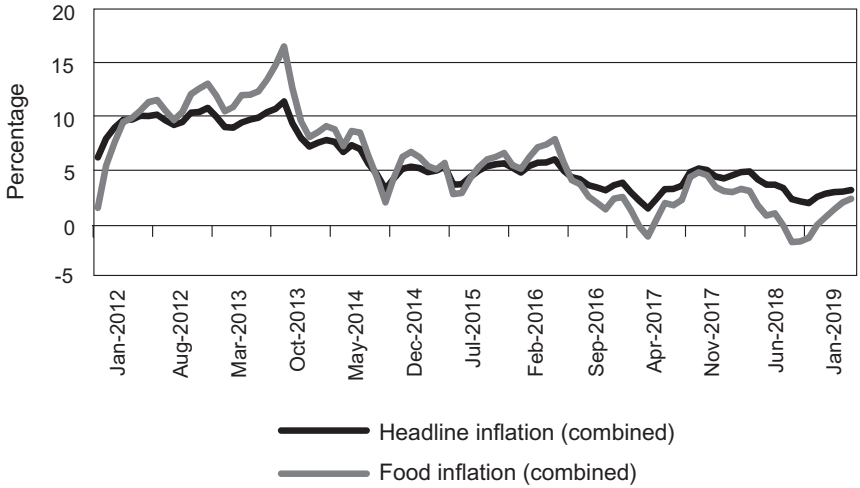
Figure 3. Headline versus core inflation, January 2012 to June 2019



Source: Ministry of Statistics and Programme Implementation. Available at www.mospi.gov.in/.

Note: Inflation measured as year-on-year growth in the respective CPI combined (for the period January 2012 – June 2019).

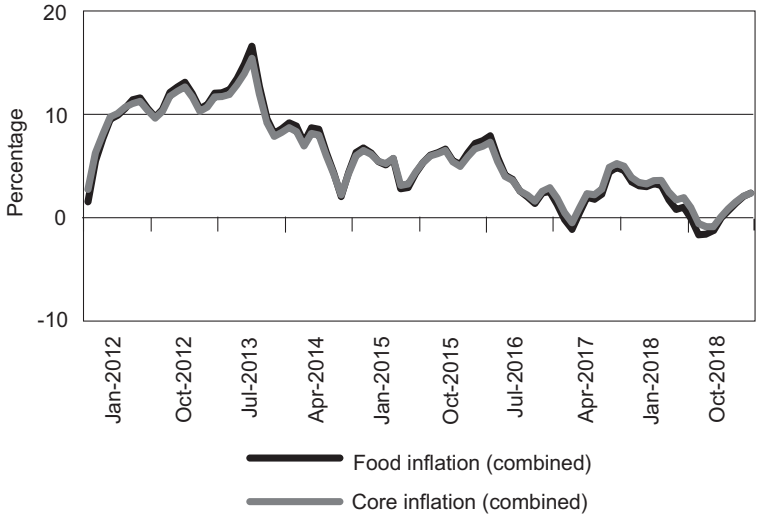
Figure 4. Headline verses food inflation, January 2012 to June 2019



Source: Ministry of Statistics and Programme Implementation. Available at www.mospi.gov.in/.

Note: Inflation measured as year-on-year growth in the respective CPI combined (for the period January 2012 – June 2019).

Figure 5. Core versus food inflation, January 2012 to June 2019



Source: Ministry of Statistics and Programme Implementation. Available at www.mospi.gov.in/.

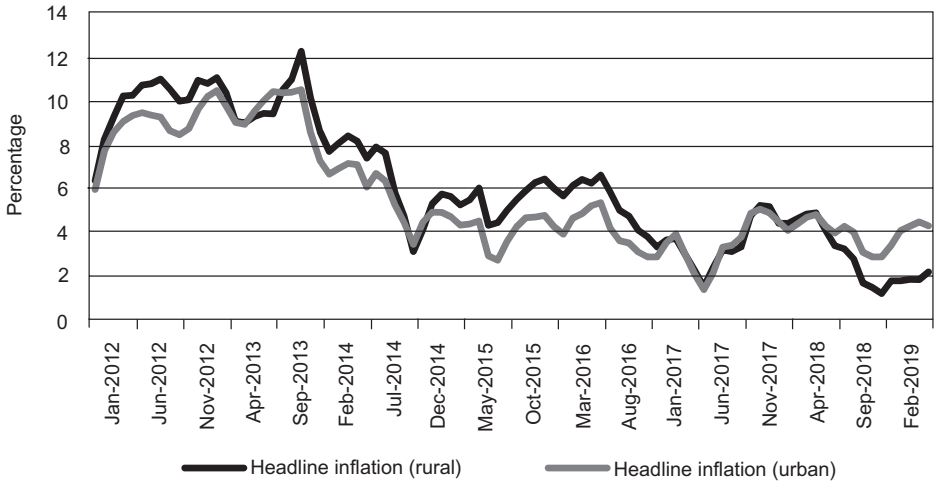
Note: Inflation measured as year-on-year growth in the respective CPI combined (for the period January 2012 – June 2019).

is also evident that the food inflation has been very high in the past few years, especially since 2016, however, it has been declining steadily post-October 2018.

The Ministry of Statistics and Programme Implementation publishes the price indices for rural areas, urban areas, and also the rural and urban combined. It is interesting to note from figure 6 that for a major part of the study period, the headline inflation in the rural areas has been higher than the headline inflation in the urban areas. Since 2018, however, the headline inflation in the urban areas seems to be higher than the headline inflation in the rural areas. In case of core inflation (figure 7), except for brief periods, there is no major rural-urban divergence. Figure 8 indicates that the food inflation has been higher in rural areas than in urban areas for three consecutive years, from January 2015 to January 2018. Accordingly, there seems to be considerable divergence in the behaviour of the inflation rates between the rural and the urban areas.

As the present study attempts to test the second round effects of rising food inflation against the backdrop of inflation targeting framework in India, a peek into the inflation projection or forecasts of the Reserve Bank of India and the actual inflation of India is warranted. Figure 9 depicts the one quarter ahead inflation forecast of the Reserve Bank of India (announced by the Monetary Policy Committee and available in its reports) and the actual inflation measured as the year-on-year growth in the CPI-C for the period January 2015 to December 2018.

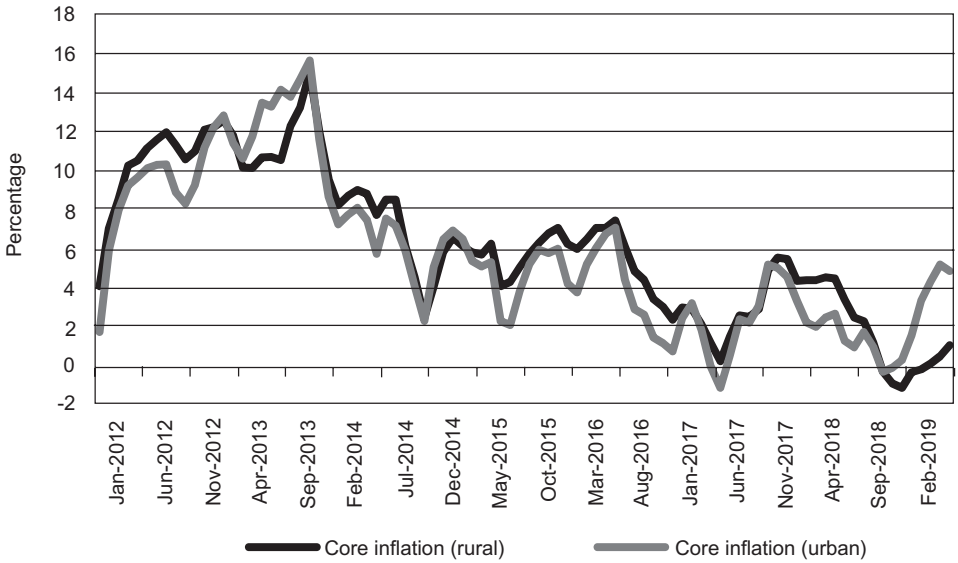
Figure 6. Headline inflation (rural versus urban)



Source: Ministry of Statistics and Programme Implementation. Available at www.mospi.gov.in/.

Note: Inflation measured as the year-on-year growth in the respective CPI.

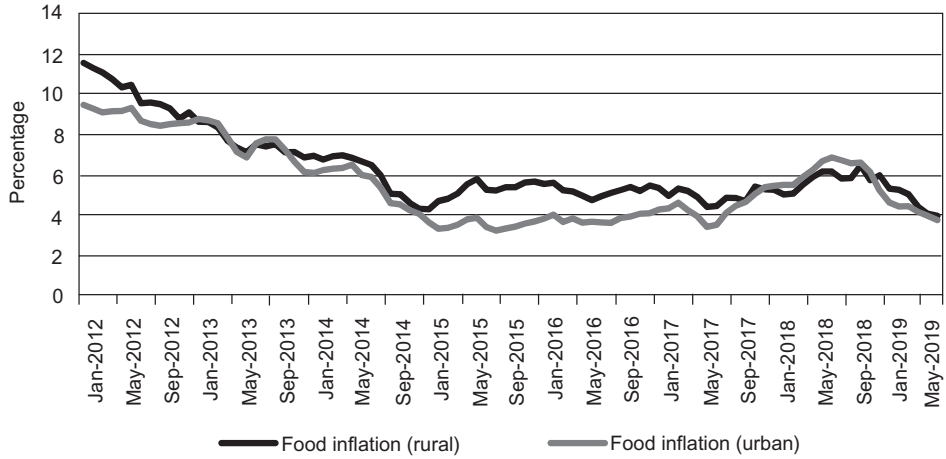
Figure 7. Core inflation (rural versus urban)



Source: Ministry of Statistics and Programme Implementation. Available at www.mospi.gov.in/.

Note: Inflation measured as the year-on-year growth in the respective CPI.

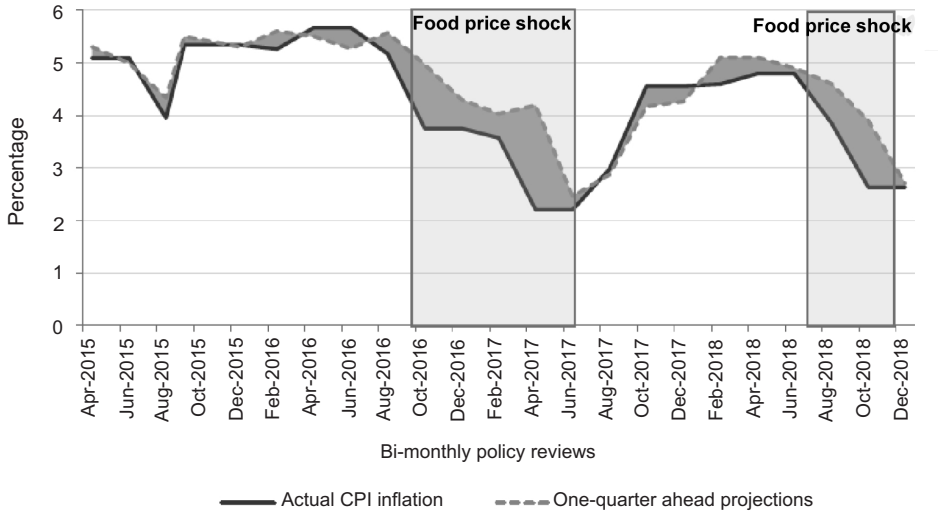
Figure 8. Food inflation (rural versus urban)



Source: Ministry of Statistics and Programme Implementation. Available at www.mospi.gov.in/.

Note: Inflation measured as the year-on-year growth in the respective CPI.

Figure 9. Actual versus projected inflation of the Reserve Bank of India for the period quarter 1, 2015 – quarter 3, 2018



Source: Reserve Bank of India, "Inflation forecasts: recent experience in India and a cross country experience", Mint Street Memo, No. 19. Available at https://rbidocs.rbi.org.in/rdocs/MintStreetMemos/19MSM02052019.pdf.

It can be clearly seen that the actual inflation diverges widely from the projected inflation only when there is a food price shock (positive or negative). The food price shock is positive when food prices are rising, and negative when food prices are falling. It is also evident that even if the food price shock continues for a prolonged period, the projected inflation (headline inflation) is either underestimated or overestimated systematically. The phases of food price shocks and the divergence between actual and projected inflation are highlighted in the figure 9. This clearly implies that the second round effects of the food price shock (food prices feeding into headline price index, which in turn gets transmitted to the core inflation), are the reason behind the widened forecast error of the inflation forecast of the Reserve Bank of India.

IV. METHODOLOGY

As the paper purports to identify the second round effects of rising food inflation in India the following research questions are dealt with:

(a) What are the implications of food inflation for headline and core inflation? Are there the second round effects?

(b) Is food inflation volatile?

(c) Are inflation expectations anchored in India?

(d) Do the inflation rates respond to monetary policy?

The first and fourth questions will be tested by estimating the Granger causality in the frequency domain (using the methodology of Lemmens, Croux and Dekimpe (2008)). The detailed methodology is as follows:

Granger causality is a commonly used technique to measure the causal relationship between variables. The present study employs a spectral density-based Granger causality test as given by Lemmens, Croux and Dekimpe (2008). The merit of this approach is that a more complete picture of the causal flow is attained by decomposing Granger causality over different time horizons. This facilitates the understanding of variations in the strength of causal flow between the two variables over the spectrum (Lemmens, Croux and Dekimpe, 2008). The spectrum can be interpreted as a decomposition of the series variance by frequency. Suppose, Xt and Yt are the two time series. Then to test for Granger causality between these time series, the white noise innovations series u_t and v_t derived after applying autoregressive moving average (ARMA) filters to Xt and Yt become the main building block. Let Su(λ) and Sv(λ) be the spectrum of the innovation series of Xt and Yt, respectively at frequency $\lambda \varepsilon [-\pi, \pi]$ given as

$$S_u(\lambda) = \frac{1}{2\pi}\sum_{k=-\infty}^{\infty}\gamma_u(k)e^{-i\lambda k} \text{ and } S_v(\lambda) = \frac{1}{2\pi}\sum_{k=-\infty}^{\infty}\gamma_v(k)e^{-i\lambda k} \quad (2)$$

Where $\gamma_u = cov(u_t\ u_{t-k})$ and $\gamma_v = cov(v_t\ v_{t-k})$ (3)

are the autocovariances of ut and vt at lag k. It is important to note that as the innovations series are the white noise process (WNP), their spectra are constant functions represented as Su(λ) = Var(ut)/2π and Sv(λ) = Var(vt)/2π, respectively. The cross spectrum between the two innovation series is the covariogram of the two series in the frequency domain. It is a complex number, defined as

$$S_{uv}(\lambda) = C_{uv}(\lambda) + iQ_{uv}(\lambda) = \frac{1}{2\pi}\sum_{-\infty}^{\infty}\gamma_{uv}(k)e^{-i\lambda k} \quad (4)$$

Where $C_{uv}(\lambda)$ is the cospectrum or the real part of the cross spectrum and the quadrature spectrum or the imaginary part is given by $Q_{uv}(\lambda).\gamma_{uv} = cov(u_t v_t)$, gives the cross covariance between ut and vt at lag k. The cross spectrum can be non-parametrically estimated as follows:

$$\hat{S}_{uv}(\lambda) = \frac{1}{2\pi}\sum_{-M}^{M} w_k \hat{\gamma}_{uv}(k)e^{-i\lambda k} \quad (5)$$

Where $\hat{\gamma}_{uv} = \hat{cov}(u_t v_t)$, the empirical cross covariance with, w_k, the window weights for k = –M to +M. The weights are assigned according to the Barlett weighting scheme, where $w_k = 1 - \frac{|k|}{M}$, and M is the maximum lag order, which is often chosen equal to the square root of the number of observations following Diebold (2001). Having derived the cross spectrum the coefficient of coherence h_{uv} (λ) can be computed. It is defined as

$$h_{uv}(\lambda) = \frac{|S_{uv}(\lambda)|}{\sqrt{S_u(\lambda)Sv(\lambda)}}\ 0h_{uv}(\lambda) < 1 \quad (6)$$

Lemmens, Croux and Dekimpe (2008) have shown that under the null hypothesis that h_{uv} (λ) = 0, the estimated squared coefficient of coherence at frequency λ with 0(λ) <π when appropriately rescaled, converges to a chi-squared distribution with two degrees of freedom. This coefficient of coherence, however, is only a symmetric measure of association between the two time series and does not indicate anything about the direction of relationship between the two processes. For the directional relationship, Lemmens, Croux and Dekimpe (2008) have decomposed the cross spectrum into three parts: (1) $S_{u_{\Leftrightarrow} v}$ the instantaneous relation between ut and vt, (2) $S_{u \Rightarrow v}$ the directional relationship between vt and lagged values of ut, and (3) $S_{v \Rightarrow u}$ the directional relationship between ut and lagged values of vt, i.e.

$$S_{uv}(\lambda) = \frac{1}{2\pi}\left[S_{u_{\Leftrightarrow} v} + S_{u \Rightarrow v} + S_{v \Rightarrow u}\right] \quad (7)$$

$$\frac{1}{2\pi}\{\gamma_{uv}(0) + \sum_{k=-\infty}^{-1} w_k \gamma_{uv}(k)e^{-i\lambda k} + \sum_{k=1}^{\infty} w_k \gamma_{uv}(k)e^{-i\lambda k}\} \quad (8)$$

Lemmens, Croux and Dekimpe (2008) have proposed the spectral measure of Granger causality based on the key null that Xt does not Granger cause Yt if and only if $\gamma_{uv}(k) = 0$ for k < 0, hence only the second part of the equation 8 becomes important, i.e.

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

Therefore, the Granger coefficient of coherence will be

$$h_{u \Rightarrow v}(\lambda) = \frac{\left|S_{u \Rightarrow v}(\lambda)\right|}{\sqrt{S_u(\lambda) Sv(\lambda)}} \qquad 0 h_{uv}(\lambda) < 1 \tag{10}$$

with the $S_{u \Rightarrow v}$ given by equation 10. In the absence of Granger causality $h_{u \Rightarrow v}(\lambda) = 0$, for every frequency between 0 and π. A natural estimator for the Granger coefficient of coherence at frequency λ is

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

with weights wk for k ≥ 0 put equal to zero in $\hat{S}_{u \Rightarrow v}(\lambda)$ (Lemmens, Croux and Dekimpe, 2008). The distribution of the estimator of the Granger coefficient of coherence can be derived from the distribution of the coefficient of coherence. Under the null hypothesis that $\hat{h}_{u \Rightarrow v}(\lambda) = 0$, for the squared estimated Granger coefficient of coherence at frequency λ, with $0 < \lambda < \pi$

$$2(n' - 1)\hat{h}^2{}_{u \Rightarrow v}(\lambda) \rightarrow^d \chi_2^2 \tag{12}$$

where $n' = T/\sum_{k=-M}^{-1} w_k^2$ and $\rightarrow^d$ implies convergence in distribution. As the weights wk with a positive index k are set equal to zero when computing $\hat{S}_{u \Rightarrow v}(\lambda)$, only the wk with negative indices are in effect taken into account. Thus, the null hypothesis of no Granger causality at frequency λ versus $h_{u \Rightarrow v}(\lambda) > 0$, is then rejected if

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

with $X^2_{2,(1-\alpha)}$ being the 1-α quantile of the chi squared distribution with two degrees of freedom (Hatekar and Patnaik, 2016).

The causality results of the inflation measures of the present study are helpful in understanding the first round and second round effects of these measures of inflation. This implies that for the first round effects to exist, there should be a causal flow from

food inflation to headline inflation, and for the second round effects to exist, there should be a causal flow from headline inflation to core inflation and headline inflation should not converge to core inflation.

For the second question, the above-mentioned inflation measures are tested for presence of autoregressive conditional heteroskedasticity (ARCH) or generalized autoregressive conditional heteroskedasticity (GARCH) effects using the ARCH-LM test. ARCH/GARCH models are models of volatility in which the conditional volatility of the residuals of a mean equation (which can be either of the following process: an autoregressive (AR) process/moving average process/autoregressive moving average (ARMA) process/OLS equation) is modelled as an AR or an ARMA process.

V. EMPIRICAL RESULTS

Steps of empirical analysis

Step I: Stationarity test of the variables used in the empirical analysis

All the variables (inflation measures and the weighted average call money rate) used in the empirical analysis were found to be stationary in level (results not reported).

Step II: ARMA filtering of the inflation measures and the weighted average call money rate to derive the innovations series for each variable

Table 2 gives the relevant ARMA models for each of the variables used in the empirical analysis derived using the Box Jenkins methodology. The innovation series for each variable is then derived as the residual series derived by subtracting the fitted values of the variables from the actual values. The residual series had become a white noise process as authenticated by the Box Pierce Test (results not reported here).

Table 2. The autoregressive moving average (ARMA) models of the variables used in empirical analysis

Variable name	ARMA model
Headline inflation	Moving average(1)
Food inflation	Autoregressive(1)
Core inflation	Moving average(1)
Weighted average call money rate	Autoregressive moving average(1,1)

Step III: Estimating the Granger causality in the frequency domain

Using Granger causality in the frequency domain, an attempt is made to investigate the first round effects and second round effects of shocks attributable to food inflation. The first round effects imply that there is a direct effect or causal flow of food inflation shock to headline inflation. The second round effects imply that from the headline inflation, there is a causal flow of the shock from to the core inflation (Portillo and others, 2016). As a result, in the present study, an attempt is made to estimate the Granger causality between the following inflation measures:

1) CPI-C (food inflation) to CPI-C (headline inflation)
2) CPI-C (headline inflation) to CPI-C (core inflation)

A statistically significant causality from headline inflation to core inflation establishes the prevalence of the second round effects.

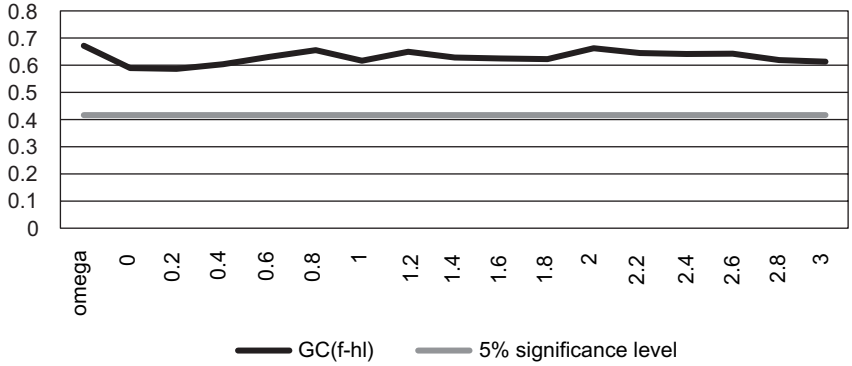
After the ARMA filtering, the number of observations of each series changed. In order to maintain uniformity, 88 observations are used to construct the relevant Granger coefficient of coherence. Hence, M, the maximum lag till which covariances have been estimated, is (the square root of the nearest perfect square of the number of observations) 9. It is important to mention here that based on the frequency of cycles, short term is defined as cycles in the frequency range of 2 to 3.14, medium term as cycles with frequency range of 1 to 2, and long term as cycles with frequency less than 1.

The Granger coefficient of coherences has been estimated in the frequency domain. Therefore, a plot of the coefficient of coherence across various frequencies is intuitive. In each of the plots on the Granger causality in the frequency domain, the Granger coefficient of coherence has been plotted on the y-axis and the frequency has been plotted on the x-axis. Figure 10 depicts the Granger causality from the food inflation to headline inflation. The straight line parallel to x-axis is the relevant Granger coefficient of coherence at the relevant significance level.

It can be observed that the Granger causality from the food inflation to headline inflation lies above the 5 per cent significance level. This implies that the Granger causality from food inflation to headline inflation is statistically significant at all frequencies. The maximum causality of 0.67 is in the long run with cycles of frequency 1. Thus, when food inflation rises, headline inflation also depicts an upward trend.

It is interesting to note from figure 11 that even the Granger causality from headline inflation to core inflation is statistically significant at all frequencies as the plot of the coefficient of coherences lies above the 1 per cent significance level. The maximum causality 0.94 occurs at a frequency of 2, namely cycles spanning 28 months or within two and a half years of the occurrence of the shock. This result establishes the prevalence of the second round effects of the food shocks.

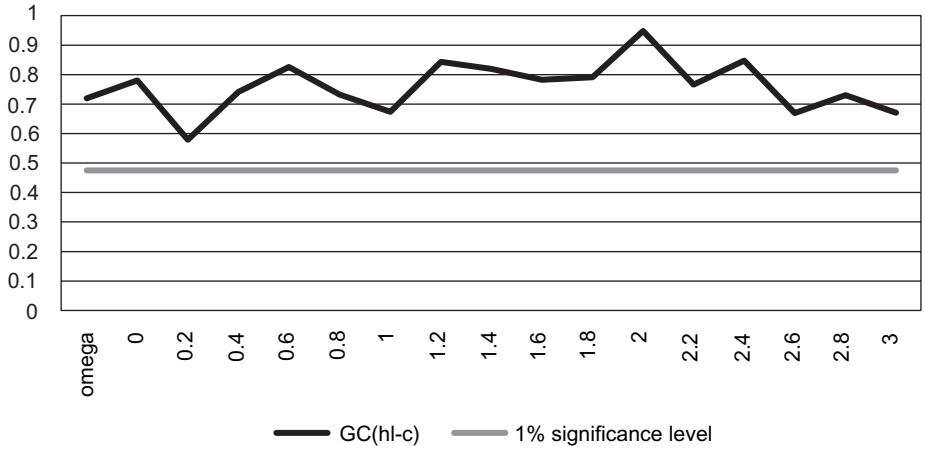
Figure 10. Granger causality in the frequency domain from food inflation to headline inflation



Source: Author's own calculations using data retrieved from the Ministry of Statistics and Programme Implementation. Available at www.mospi.gov.in/.

Note: GC, Granger causality.

Figure 11. Granger causality in the frequency domain from headline inflation to core inflation



Source: Author's own calculations using data retrieved from the Ministry of Statistics and Programme Implementation. Available at www.mospi.gov.in/.

Note: GC, Granger causality.

Step IV: Testing the inflation measures for presence of volatility

The inflation measures were tested for presence of volatility using the ARCH-LM test, the null of no ARCH effects for all the three inflation measures was not rejected (table 3).

Table 3. ARCH-LM test results of the inflation measures

Inflation measure	ARCH-LM statistic	P-value
Food inflation	7.8499	0.6434
Core inflation	4.1677	0.9394
Headline inflation	5.7124	0.8388

Step V: Quantifying the gap between the actual inflation and the households' inflation expectations

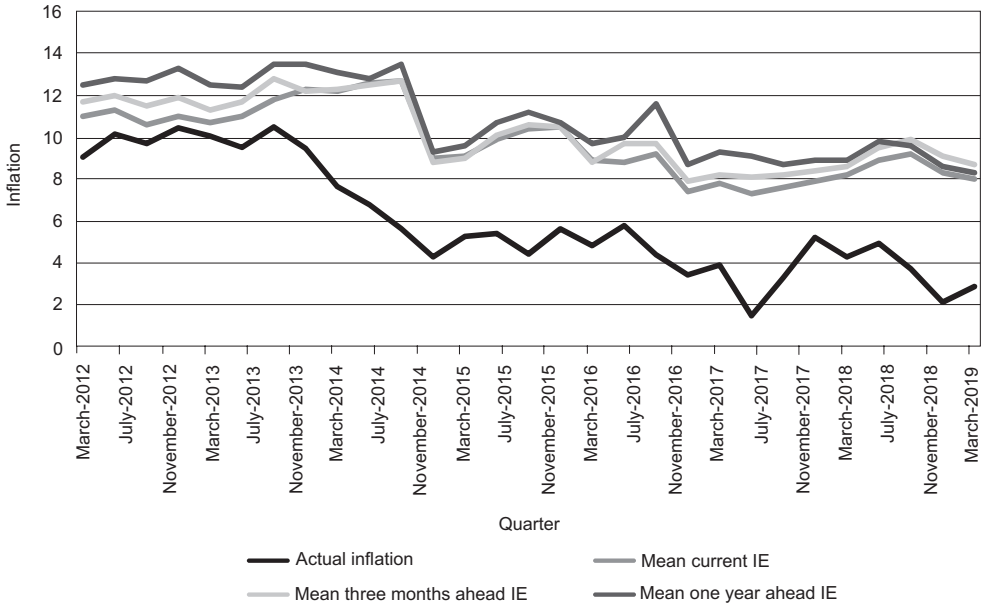
The Reserve Bank of India conducts and publishes the Inflation Expectations Survey of Households on a quarterly basis. This survey is conducted in eighteen cities of the country and derives qualitative and quantitative responses from the households on current, three months ahead, and one year ahead inflation rate. It is important to note that the inflation expectations influence the wage bargaining process and the future inflation. Under an inflation targeting framework, the Reserve Bank of India has to anchor inflation expectations of the households to achieve the targeted inflation with a minimum cost of disinflation. The Inflation Expectations Survey of Households (figure 12) reveals that the inflation expectations of the households for the current, three months ahead, and one year ahead periods are considerably higher than the actual inflation, especially since 2013. While the average actual inflation for the entire sample period, March 2012 to March 2019, was 6 per cent, the mean expected inflation for the current, three months ahead and one year ahead were 9.77 per cent, 10.22 per cent, and 10.87 per cent, respectively.

Further insights into the gap between the actual and expected inflation of the households can be derived by estimating the mean error (ME) and root mean square error (RMSE) of the inflation expectations of the households with respect to the actual inflation. ME and RMSE are estimated as given in equations 14 and 15 below:

$$ME = \frac{1}{n}\sum_{i=1}^{n}(\pi_{i,a} - \pi_{i,e}) \tag{14}$$

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(\pi_{i,a} - \pi_{i,e})^2} \tag{15}$$

Figure 12. Actual inflation versus household inflation expectations (for mean current, mean three months ahead and mean one year ahead)



Source: Reserve Bank of India, "Inflation Expectation Survey of Household, June 2019".

From table 4, it can be clearly seen that the mean error in all the three cases of expected inflation for the entire sample is very high. As the value of mean error is negative, the households have been overestimating inflation. The root mean square error also clearly highlights a similar picture and clearly reveals that, on an average, the expected inflation is 3 to 4 per cent above the actual inflation. It can also be seen that as the forecast horizon increases, the error is also increasing.

Table 4. Mean error and root mean square error of the inflation expectations of households

	Mean current inflation expectation	Mean three months ahead inflation expectation	Mean one year ahead inflation expectation
Mean error	-3.77913	-4.22051	-4.87224
Root mean square error	4.180188	4.532671	5.091446

Source: Author's own calculation using data on inflation expectations of households, derived from the Reserve Bank of India, "Inflation Expectation Survey of Household, June 2019".

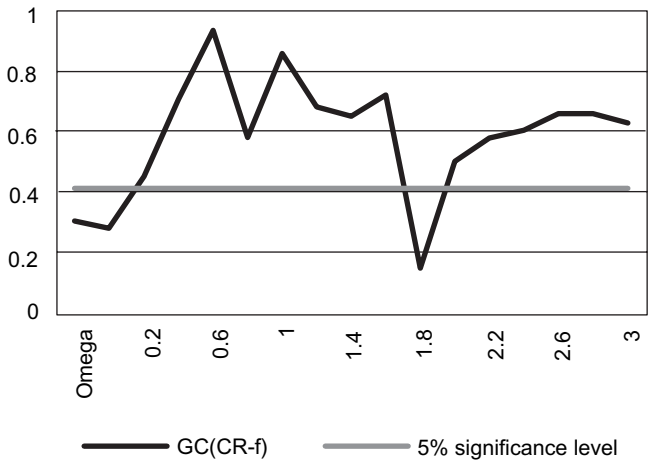
The gap between the actual and expected inflation may be because "the food and fuel shocks have high persistence on households' inflation expectations, which impart stickiness to core inflation" (Dholakia and Kadiyala, 2018). The second round effects found in step four are the outcome of the unanchored inflation expectations; it is clear that the Reserve Bank of India is failing to anchor inflation expectations of the households.

Step VI: Estimating the Granger causality from the monetary policy to the inflation measures

Against the backdrop of unanchored inflation expectations and the prevalence of the second round effects of food inflation, it would be intuitive to test if monetary policy is able to influence these inflation measures. As a result, the Granger causality in the frequency domain was estimated from the call money rate (proxy for repo rate, which is the policy rate of the Reserve Bank of India) to all the three inflation measures. The results of the causal flow are depicted in figures 13, 14 and 15.

Figure 13 shows that the Granger causality from weighted average call money rate to food inflation is statistically significant from the frequency 2.2 to 3.14 and 0.6 to 1.8, which are cycles of short-term frequency and medium-term frequency. The maximum causality is at cycles with a frequency of 1.2 in the given sample. This implies that

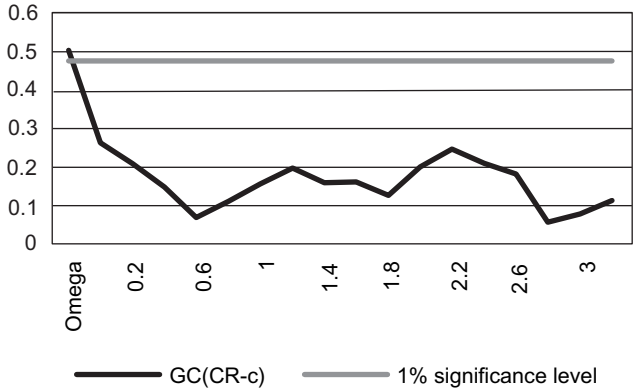
Figure 13. Granger causality in the frequency domain from call rate to food inflation



Source: Author's own calculations using data retrieved from the Ministry of Statistics and Programme Implementation. Available at www.mospi.gov.in/.

Note: GC, Granger causality.

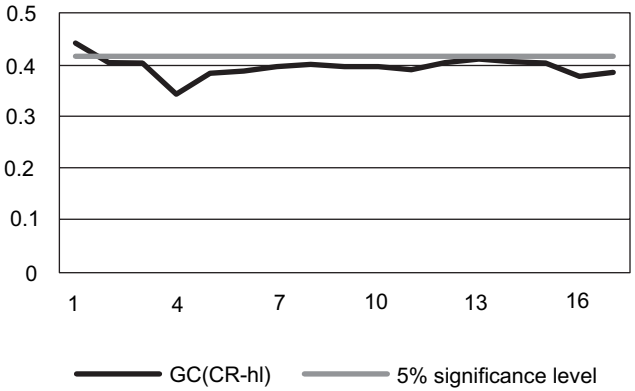
Figure 14. Granger causality in the frequency domain from call rate to core inflation



Source: Author's own calculations using data retrieved from the Ministry of Statistics and Programme Implementation. Available at www.mospi.gov.in/.

Note: GC, Granger causality.

Figure 15. Granger causality in the frequency domain from call rate to headline inflation



Source: Author's own calculations using data retrieved from the Ministry of Statistics and Programme Implementation. Available at www.mospi.gov.in/.

Note: GC, Granger causality.

monetary policy in India is able to influence the food inflation in the short term and the medium term. This result is contrary to conventional wisdom that monetary policy cannot influence food inflation. This may be because the CPI-C food index comprises a number of manufactured items, which might respond to a policy impulse. Figure 14, however, shows that monetary policy influences the core inflation only in the long run with cycles of 0 frequency. Figure 15 again shows that the Granger coefficient is not significant across all frequencies at 5 per cent significance level, except at zero frequency, only in the long run. This clearly implies that monetary policy is ineffective in the short run and medium run in India.

VI. DISCUSSION OF RESULTS AND CONCLUSION

Results

(a) The causality tests reveal the presence of the first round effects, namely the presence of causality from food inflation to headline inflation, which is expected. They also show that a significant causality from headline inflation to core inflation exists. Causality from headline inflation to core inflation implies the presence of the second round effects. Rising food inflation feeds into the headline inflation, which further feeds into core inflation because of rising inflation expectations, giving rise to an upward push to the underlying trend in inflation. As a result, the headline inflation and core inflation diverge.

(b) The volatility results of the inflation measures clearly reveal that none of the inflation measures are volatile. Accordingly, food inflation in India cannot be treated as transitory.

(c) Mean error and root mean square error of the inflation expectations for the given sample clearly reveals that households are overestimating future inflation as the Reserve Bank of India is failing to anchor inflation expectations. This is the reason behind the second round effects.

(d) The Granger causality from the call rate to the inflation measures clearly reveals that policy is able to influence only the food inflation in the short and medium run. It influences the core inflation and headline inflation only in the long run.

Conclusion

It can, therefore, be concluded that second round effects of food inflation are highly significant in the case of India. These second round effects occur as inflation expectations are not anchored. This calls for a renewed and vital role of the Reserve Bank of India in anchoring inflation expectations of the households through effective communication and transparency.

In addition, failure of monetary policy in influencing the headline inflation in the short and medium run, warrants the need to revitalize the transmission mechanism of monetary policy in India.

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