The Impact of Shocks on Core Inflation; Evidence from India

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Abstract

This paper attempts to investigate the impact of demand and supply shocks on core inflation in India. Firstly, it calculates core inflation through asymmetric trim mean approach and secondly autoregressive distributed model is used to explain the dynamic effects of shocks on core inflation. Empirical findings based on ARDL bound test confirms the existence of long run relationship between core inflation with other macroeconomic variables and CUSUM and CUSUMSQ test show stability of coefficients in the model. Overall, the response of core inflation to demand shock is high in case of real variables as compared to monetary variables and its response to skewness-based supply shock is high as compared to food and fuel inflation.

***Key words*:** Headline Inflation, Core Inflation, Demand Shocks, Supply Shocks, Asymmetric trimmed Mean, Autoregressive Model, Bound Test.

***JEL Classification*:** C22, E31, E51 E52

Section - I
Introduction

Targeting inflation within the specific range has become the major objective of the monetary policy. Recently, there are two majors development in the macroeconomics management in India. Firstly, announcement of a new monetary policy committee as a part of a new framework, for the task of deciding the benchmark policy rates, to target inflation at a specific level. Secondly, formal declaration of inflation targeting as a new monetary policy objective, where Consumer Price Index (CPI) acts a nominal anchor to target inflation at the rate 4 percent with a band of 2 – 6 percent**.**

Monetary policy works with influencing aggregate demand in an economy. Both demand and supply shocks create large variations in the relative prices. Headline inflation consists of both non-core part or the transitory price changes and the core part or permanent price changes. It takes the form as;

$$[(\pi_{ht}) = C + \beta(\pi_{ct}) + T_t]$$

Or

$$T_t = [(\pi_{ht}) - C - \beta(\pi_{ct})]$$

Where, (π_{ht}) = Headline inflation, (π_{ct}) = Core inflation and T_t = Transitory price changes

The major challenges with the monetary policy is to forecast inflation expectation accurately. Forecasting using headline inflation, which consists of both core price and the transitory price movement can cause ineffectiveness in the monetary policy decision making. (Lafleche, 2006) argued that monetary policy operates with lag; hence, price rise due to temporarily shocks will be corrected by its own and does not require monetary policy action to deal such situation.

In addition to this, headline inflation is highly volatile due to temporarily price changes mainly because of food and oil price shocks in the short run, which makes it ineffectiveness in the monetary policy decision making. Taking decision to set the benchmark policy rate through headline inflation can be misleading for the policy purpose. However, the policy decision can be effective, if one can forecast on core inflation, which eliminates all the volatile components from the headline inflation and can be considered as a good trend for the headline inflation. Hence, the study has attempted to empirically examine the core inflation for India by using CPI headline inflation and further analyse the impact of macroeconomics variables on core inflation.

The study is organised as follows, introduction is followed by literature review in section 2. Section 3 discusses the objectives of the study. Data description and methodology for constructing core inflation as well econometric modelling for understanding inflation dynamics is discussed in section 4. Section 5 and 6 discuss the empirical findings and conclusion of the study.

Section - II
Literature Survey

(Otto Eckstein, 1981) has first coined the concept of core inflation and defined it as *"the trend increase in the cost of factors of production that originates in the long-term expectations of inflation in the minds of households and businesses."* Later, the empirical and theoretical works of (Byran and Ceechetti, 1994) (Blender, 1997) have given more strong arguments in favour of using core inflation in making policy decision as it can be used as a well-defined underlying trend for headline inflation that persist for a longer period and therefore useful for near and medium term inflation forecasting. At the global level, research has been conducted for construction of core inflation based on both conventional exclusion based criteria and statistical measures by (Bryan and Cecchetti, 1994) (Quah and Vahey, 1995) (Rich and Steindel, 2005) (Blinder and Reis, 2005) (Marques, et al., 2003) (Mishkin, F. S., 2007) (Bodenstein et al., 2008) and (Gamber et al., 2015). In India (Mohanty et al., 2000) (Kar, 2009) (Raj and Mishra, 2011) (Ramachandran et al., 2014) and (Naresh and Motilal, 2015) have worked on the measure of core inflation. There are different methodology for the construction of core inflation, namely the statistical measure and conventional exclusion based measure. Conventional exclusion-based measure removes the highly volatile elements from the headline or the total inflation such as food and fuel inflation. There is a pre-specific list of items, which is define to have transitory price movement. However, there are arguments put against of this approach is that the excluded item may consist of relevant information about the underlying inflation. Therefore, conventional exclusion-based measure may not be considered as the best measure for core inflation. On the other hand, the statistical measure such as trimmed mean, weighted median approach, moving average method, exponential smoothened series, HP Filter, common component method are more flexible and appropriate approach due to their statistical property to exclude the impact of different components each months, based on their extreme price movement at the specific point of time.

Bryan and Cecchetti (1994) have supported the significance of the statistical measure for core inflation through weighted median method whereas (Clark, 2001) have favoured the approach of trimmed mean method for the calculation of core inflation. According to them, statistical measures remove the highly volatile components, which arises due to temporarily supply shocks. Such shocks create large movement in the prices of the components, making the overall inflation highly volatile. Bernanke (2007) stated that monetary policy works with lag and therefore policy makers must focus on the economic outlook. The total inflation or the headline inflation is highly volatile due to temporarily shocks in food and energy components; therefore, core inflation (which exclude the highly volatile components) can be the better gauge for forward looking approach for policy forecasting. Mishkin, F. S (2007) and (Bodenstein et al., 2008) study suggest optimal monetary policy with distinct core and headline inflation rates, while (Kiley, 2008) study examined whether the shock to headline inflation feedback into core inflation and does the existence and strength of that feedback differ across measures of core inflation. Kiley examines both Consumer Price Index (CPI) and the Personal Consumption Expenditure deflator (PCE) and considers the less food and energy (LFE) measures as core inflation. Alkhareif and Barnett (2015) analyse core inflation indicators for Saudi Arabia for the period of March 2012 to May 2014 using two alternative approaches: the exclusion method (excluding food and housing/rent) and the statistical method. The findings suggest that excluding food and housing/rent inflation is more volatile than the overall CPI inflation and weakly correlated with headline inflation. In contrast, the statistical core inflation is relatively more stable, less volatile and exhibits a stronger correlation. This combination of lower volatility and higher correlation with headline inflation makes the statistical method a much better choice for policymakers. Gamber et al. (2015) analyse the dynamic relationship between headline and core inflation across monetary policy regimes for both the Consumer Price Index and Personal Consumption Expenditure deflator by using a series of bivariate vector autoregressions (VAR). The findings suggest that the shock to headline inflation would have a more persistence response in core inflation. On the other hand, when the monetary policy is not accommodative, headline shocks are expected to have the small persistent effect on core inflation. Edward and Saeed (2017) study propose a model for nowcasting headline and core inflation in the U.S. consumer price index and price index for personal consumption expenditures that relies on small data series. Simple univariate and multivariate regressions is used to forecast the inflation.

Empirical studies to capture the dynamic effects of macroeconomic indicators on Core inflation:

Bhattacharya and Patnaik (2014) analyse the monetary policy analysis for inflation targeting framework in India by applying a semi-structural New Keynesian open economy model for anchoring inflation expectation. The underlying framework is a standard New-

Keynesian model with rational expectations, nominal and real rigidities with aggregate demand having a role in output determination. The framework blends to a reduced form version of the forward-looking general equilibrium model with New-Keynesian features. The finding suggest that the positive domestic aggregate demand shocks coupled with accommodative monetary policy and supply-side pressure have resulted in unanchored monetary policy. Similarly, a study by (Rina, 2013) has look into the overview of inflation dynamics and the monetary policy transmission in Vietnam. In study has considered CPI inflation as the weighted function of the changes in the prices of tradable and non-tradable goods. The rate of changes in the prices of tradable goods is the function of the nominal exchange rate and the international price of the tradable goods. The inflation model is empirically analyse by using VAR model. The short and medium-term elasticities of inflation were computed from the impulse responses based on a Cholesky decomposition. The findings based on impulse response function suggest that in the short run; inflation is affected by nominal effective exchange rate whereas in the medium run GDP growth and money supply are the principal drivers of inflation. Moses (2013) study applied the P-star model of inflation to empirically analyse the performance of Kenyan economy over the time of 1960 to 2011. The empirically tested results show that past inflation contributes significantly to current inflation suggesting a high level of persistence of inflation and the domestic price gap is found to be more significant in predicting Kenya's rate of inflation when compared with the foreign price gap. Darbha and Patel (2012) study inflation dynamics by using the novel measure of inflation known as Pure Inflation Guages (PIG) by decomposing the price movement into (i) aggregate shocks that have equal proportional effects on all sector prices, (ii) aggregated relative price effects; and (iii) sector-specific and idiosyncratic shocks. The findings show that Wholesale Price Index (WPI) inflation by the end of 2008-09 had declined to about 1 percent from about 8 percent in 2007-08. The decline in the level of headline inflation in 2008-09 have conveyed the authorities to adopt the more tightening policy to look at inflation measures corrected for sectoral and idiosyncratic shocks.

Section – III
Objective of the Study

1. To empirically understand and capture the significant impact of demand and supply shocks on core inflation in India with respect to time.

2. To understand, between the two factors, i.e. demand side factors and supply side factors which one has more influence on core inflation in India.

Section – IV
Data Description and Methodology

4.1 Data Description

The empirical study has been carried out by using monthly time series macroeconomic data covering the sample period of January 2012 to December 2017 with (2011-12) as base year price. Combined Consumer Price Index (CPI) Y-o-Y inflation data is used to calculate core inflation through asymmetric trimmed weighted mean approach and conventional exclusion based measure (excluding food, excluding energy and excluding both food and energy) from CPI headline inflation data.

For the proxy of demand shock, macroeconomics variables such as output gap, money growth, interest rate, effective exchange rate is considered. On the other hand, fuel inflation, food inflation, and skewness-based inflation, which is calculated by subtracting core inflation from headline inflation are considered as three alternatives supply shocks.

In the present study, output gap is defined as the difference between the actual output of an economy from its potential output. Potential output is the maximum amount of goods and services that an economy can turn out when it is at the most efficient. In the study, Hodrick–Prescott (HP) decomposition is used to calculate the long – term trend or the potential output. The deviation from the real GDP from its long-term trend is considered as an output gap in the present study. Due to unavailability of monthly data on real GDP in India, index of industrial production (IIP) is used as a proxy for real GDP. Before calculating the output gap, we filtered the seasonality components using the Census X12 method.

To reflect the behaviour of monetary policy, weighted average call money rate is considered as a proxy for the short-term interest rate and money growth is calculated from the money stock (M3). For the external demand shock on core inflation, NEER (trade weighted - 36 currency) is used as a proxy for effective exchange rate.

The time series data is taken from Ministry of Statistics and Programme Implementation (MoSPI) and Reserve bank of India, Database on Indian economy.

4.2 Methodology

This section is divided into two parts. Firstly, it discusses the methodology of calculation of core inflation through asymmetric trimmed weighted mean approach. Secondly, it discusses the methodology to capture the dynamic effects of core inflation through Autoregressive Distributed Model and Bound Test approach.

4.2.1 Calculation of Core Inflation

Let, p_{it} is the price index of individual items (i) in period (t) and w_i is the weight[1] for each commodity in the CPI basket such that $\sum_{i=1}^{n} w_i = 1$. (Here, {n} represents the number of a basic commodity in the CPI basket.)

Therefore,.

$$P_t = \sum_{i=1}^{n} P_{i,t} \times w_i$$

Now, for calculating time-varying weights w_{it} , multiply the price index of each commodity with their respective weights w_i such that,

$$w_{i,t} = w_i \times \frac{P_{i,t-12}}{P_{t-12}}$$

For calculating aggregate Y-o-Y inflation rate(π_t)

$$\pi_{i,t} = \frac{P_{i,t} - P_{i,t-12}}{p_{t-12}}$$

and

$$\pi_t = \sum_{i=1}^{n} \pi_{i,t} \times w_{i,t}$$

Where π_t represents the aggregate Y-o-Y inflation rate of all items in the CPI basket of commodity.

4.2.2 Distribution of Inflation data

To know the distribution of the inflation data, we have calculated the skewness and kurtosis. It is calculated through the K^{th} weighted central moments (m) of the cross-sectional distribution of inflation data at time t. It is define as

$$m_{kt} = \sum_{i=1}^{n} \frac{w_{i,t} (\pi_{i,t} - \pi_t)^k}{N}$$

Now, Karl Pearson moments coefficient of skewness (SK_t) and kurtosis (KU_t) can be expressed as

$$(SK_t) = (m_{3t})^2 / (m_{2t})^3$$

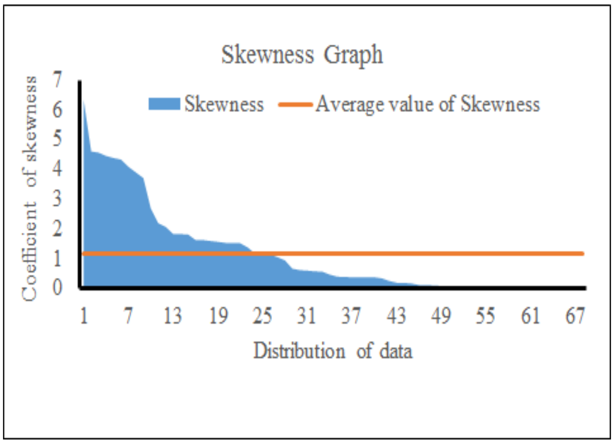
$$(KU_t) = (m_{4t}) / (m_{2t})^2$$

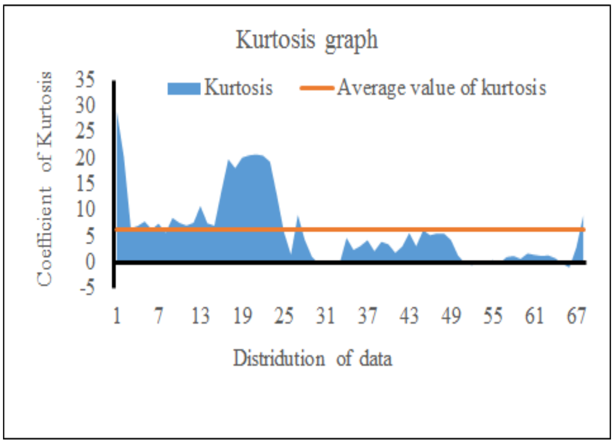
The coefficient of the skewness (SK_t) measures the lack of symmetric distribution of an inflation data around its mean, whereas the coefficient of kurtosis (KU_t) measure the excess

[1] Weight for each component of CPI is collected from Ministry of Statistics and Programme Implementation

kurtosis relative to the normal distribution of a data. In figure 1, which shows the distribution of data indicates that the price distribution is more right skewed indicating that the price distribution is positively skewed. The average value of the coefficient of skewness is 1.145. Similarly, the average value of the coefficient of kurtosis is 6.183, indicating positive price distribution of CPI headline inflation data in India. However, data distribution is highly skewed and therefore, asymmetric trim weighted mean approach is the suitable measure to calculate core inflation.

Figure 1: Distribution of Inflation data





Average value of Skewness = 1.145 **Average value of kurtosis = 6.183**

4.2.3 Asymmetric Trimmed Weighted Mean Method

Symmetric trim mean is used when the data is normally distributed. In this, the right and the left side of the distribution of data is equally trimmed. On the other hand, asymmetric trim mean is calculated by choosing the percentage of left trim and the right trim of the given distribution of data. Before proceeding to trim the data, it is convenient to arrange the data in ascending or descending order with their respective weights and express the data in percentile score ranging from 1 to 100. Now, for trimming, we need to define the centre (c) and the percentage of trim (t). For a symmetric distribution of data, the centre should be defined as 50, whereas for the asymmetric distribution, the centre should be greater or less than 50.

The percentage of left trim and the right trim is defined as (L, R), where L = {(c + p – 50) and R = (c – p + 50)}. Here, c denotes centre and p denotes percentage of trim. Suppose if the centre is fixed as 54 and the percentage of trim is fixed as 10, then it gives the percentile interval (L, R) as (14, 94) which is obtained by asymmetrically trimming the value of the price distribution which is less than 14th percentile and more than 94th percentile. The percentage of a trim mean is obtained by trimming 14 percent of the smallest and 6 percent of the largest price changes. Similarly, if the centre is fixed as 50 and the percentage of trim is fixed as 10, then it gives the percentile interval (L, R) as (10, 90) which is obtained by symmetrically trimming the value of the price distribution which is less than 10^{th} percentile and more than 90^{th} percentile. In this case, the percentage of a trim mean is obtained by symmetrically trimming 10 percent of the smallest and the largest price distribution.

Now, Core inflation $\pi_{c,t}$ for the period (t) is defined as the weighted average of the commodity prices after trimming. It takes the form as;

$$\pi_{c,t} = \sum_{j=1}^{n}(w'_{j,t}\ \pi'_{j,t})\ \ /\ \sum w'_{j,t}$$

Here, j represents the number of items in the CPI basket of commodity after trimming.

In the present study, the percentage of trim mean (p) is set at an interval of 5 starting from 5 percent to 45 percent and the centre (c) is chosen between 40^{th} percentile to 60^{th} percentile at an interval of 0.50 percentile point. Thus, a total (369 time series of trimmed means) are computed over the sample period of January 2012 to December 2017. The computational and calculation of 369 trimmed means time series is performed through R - Studio package.

4.2.4 How to decide the best measure of core inflation?

To identify the best measure of core inflation, one can rely on the three properties of core inflation i.e. firstly, It should be stable and less volatile than the headline inflation. Secondly, it should able to track the trend of the headline inflation and thirdly, it should able to predict the future headline inflation. To test these properties of core inflation, we have formulated three condition

1. First Condition – Property of Unbiasedness

For a good forecasting, it is necessary that the residual should be normally distributed; it should be stationary at level with zero mean, constant variance and uncorrelated.

$$[(\pi_{ht}) = C + \beta(\pi_{ct}) + U_t]$$

$$U_t = [(\pi_{ht}) - C - \beta(\pi_{ct})$$

Where, (π_{ht}) is the headline inflation, (π_{ct}) is the Core inflation and U_t is the white noise error term.

In the present study, headline and core inflation is non-stationary at a level and become stationary at first difference, therefore the residual obtain after regressing headline inflation on core inflation should be stationary at level. After regressing headline inflation on each 369 trimmed mean time series or core inflation, the residual of 141-time series is found be stationary at a level I (0) with one percent level of significance.

2. Second Condition – Core inflation as an attractor of headline inflation

Core inflation is derived from trimming skewed prices from the headline inflation; therefore, there exist a long run relationship between the two. However, in the present study, both headline and core inflation is non-stationary at level and become stationary at first difference, therefore, the long-run cointegrating relationship is explained through Error Correction Mechanism (ECM) model, which takes the form as,

$$\Delta\pi_{ht} = \sum_{i=1}^{n} \alpha_i \Delta\pi_{h_{t-i}} + \sum_{j=1}^{m} \beta_j \Delta\pi_{c_{t-j}} - \varepsilon_{t-1} + u_t$$

Here, ε_{t-1} is the Error Correction Term (ECT) or $\varepsilon_{t-1} = y(\pi_{h_{t-1}} - \pi_{c_{t-1}})$ and (n and m) represents the number of lags of the headline and the core inflation. In order to prove the attractor property; the null hypothesis of no attraction i.e. $(y = 0)$ cannot be accepted.

As an attractor property, the ECT should exhibits the long-run relationship between the headline and the core inflation. Therefore, a negative and significant coefficient of the ECT (y) exhibits the attraction property and describe the long – run causality between the headline and the core inflation.

However, before proceeding, it is necessary to calculate the rank of a cointegrating equation. Johansen cointegration test (1991, 1995) using T- Statistics and Maximum Eigen Value is used to identify the number of a cointegrating equation. Out of the 141 trimmed mean series, 111-time series passes the Johansen cointegration test. Now, the ECM model is run for the 111 trimmed time series. Out of 111-time series, 74-time series pass with the second condition. In this, the error correction term of each trimmed mean time series is negative and significant and therefore we reject the null hypothesis of no attraction at one percent level of significance. For selecting the optimum number of lags values, Akaike information criterion (AIC) is used in the model and the maximum lag value is taken as 3.

3. Third Condition – Property of Exogeneity

In order to show the exogenous property of core inflation, we have run the Error Correction Model on 74 trimmed mean time series, which takes the form as

$$\Delta\pi_{ct} = \sum_{k=1}^{o} e_k \Delta\pi_{c_{t-k}} + \sum_{l=1}^{p} d_l \Delta\pi_{h_{t-l}} - \delta_{t-1} + v_t$$

Here, δ_{t-1} is the Error Correction Term (ECT) or $\delta_{t-1} = x(\pi_{c_{t-1}} - \pi_{h_{t-1}})$ and (o and p) represents the maximum number of lags of core and headline inflation.

For testing the exogeneity of core inflation, we have applied weak exogeneity test and strong exogeneity test.

Weak Exogeneity test

$\boldsymbol{First\ Null\ Hypothesis} = \boldsymbol{H1_0} = (\boldsymbol{x = 0}) -$ It Implies there is no long-run association. It is tested through T-statistics.

$\boldsymbol{Second\ Null\ Hypothesis} = \boldsymbol{H2_0} = (\boldsymbol{d_1 \dots d_p = 0}) -$ It indicates that the lag values of headline inflation has no effect on core inflation. The joint effects of the lag values of the headline inflation are tested through block exogeneity wald test.

B. Strong Exogeneity test

$\boldsymbol{Third\ Null\ Hypothesis} = \boldsymbol{H3_0} = (\boldsymbol{x = d_1 = \cdots = d_p = 0})$

The acceptance of the null hypothesis implies that core inflation is exogenously determine by its own lag values. To perform the strong exogeneity test, we use Wald Statistic, which indicates joint effects of regressors on the dependent variable. Wald statistics assume the null hypothesis $(x = d_1 = \cdots = d_p = 0)$ against the alternative hypothesis.

Out of 74 trimmed series, 67 series pass the weak exogeneity test. Out of 67-time series trimmed mean, we have selected those trimmed means series, which strongly accept the null hypothesis, i.e. whose p-value is 0.9 or approximately one. Based on the first and second null hypothesis, the p-values of [(47, 10); (48, 20); (48.5, 20); (51.5, 10); (52, 10); (52.5, 10); (53, 10)] trimmed mean time series is approximately near to one. Therefore, the strong exogeneity test is applied to these seven trimmed mean time series.

Table 1: Strong Exogeneity Test (Wald statistics)

Trimmed Mean	F- Statistic	(DF)	P-Value
(47, 10)	0.056	(3, 59)	0.938
(48, 20)	0.236	(3, 59)	0.947
(48.5, 20)	0.136	(3, 59)	0.938
(51.5. 10)	0.196	(3, 59)	0.899
(52, 10)	0.250	(3, 59)	0.861
(52.5, 10)	0.058	(3, 59)	0.982
(53, 10)	0.058	(3, 59)	0.982

Table 1, represents the strong exogeneity test. The joint effect of the regressors is tested through F statistics. The null hypothesis i.e. $H3_0 = (x = d_1 = \cdots = d_p = 0)$ cannot be rejected. Hence, the insignificant F- statistics suggests that there is no joint effect of the regressors on core inflation. Core inflation is only affected by its own past values.

4.2.5 Variance and the Relative Variance of Core Inflation

To select the best core inflation among the selected seven alternatives core inflation, which passes all the three condition, we have chosen the variance and the relative variance criteria. Among the seven alternatives of core inflation, the one that indicates the smallest variance and the relative variance, is considered as the best measure of core inflation and therefore could be considered as a good trend for headline inflation. The least variance and the relative variance indicates the small volatility between core inflation and headline inflation. Among seven alternatives, the variance and relative variance of (48.5, 20) time series core inflation is the smallest and therefore it can be considered as an optimal measure of core inflation in the class of all trimmed mean time series.

Table 2: Variance and Relative variance of Core Inflation

CPI Inflation	Variance	Relative Variance
Headline inflation	3.91	1
(47_10)	3.75	0.96
(48_20)	2.88	0.74
(48.5_20)	2.70	0.69*
(51.5_10)	3.79	0.97
(52_10)	3.79	0.97
(52.5_10)	3.35	0.86
(53_10)	3.35	0.86

Note: Relative variance = variance of core inflation / variance of headline inflation

4.2.6 Different Measure of Core Inflation

Further, the study has also calculated the core inflation through conventional exclusion based measure i.e. excluding food, excluding energy and excluding food and energy along with symmetric trim mean measure of core inflation. The purpose behind calculating core inflation through different method is to understand, which measure of core inflation can give a good trend for the underlying headline inflation. All the measure of core inflation has shown the long run association with the headline inflation. The error correction term (ECT) is negative and significant except for CPI _ excluding food and energy measure.

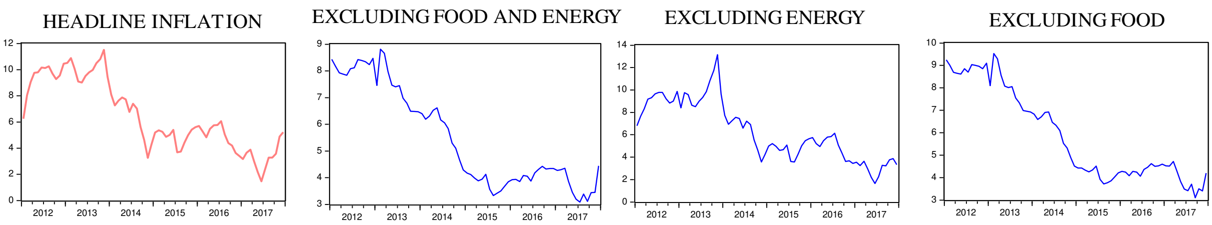
Additionally, the root mean square error test (RMSE) for the conventional exclusion based measures that is (CPI _ Excluding food, CPI _ Excluding energy and CPI _ Excluding food and energy) is greater than one, indicating that these measures of core inflation are not good for predicting headline inflation. However, the RMSE of symmetric trimmed mean series i.e. [(50, 5) (50, 10) (50, 15) (50, 20)] have performed better, but the core inflation calculated from asymmetric trim mean approach i.e. (48.5, 20) trimmed series is observe to have the least RMSE indicating that it is good fit for predicting the headline inflation.

Table 3: Best Measure of Core Inflation

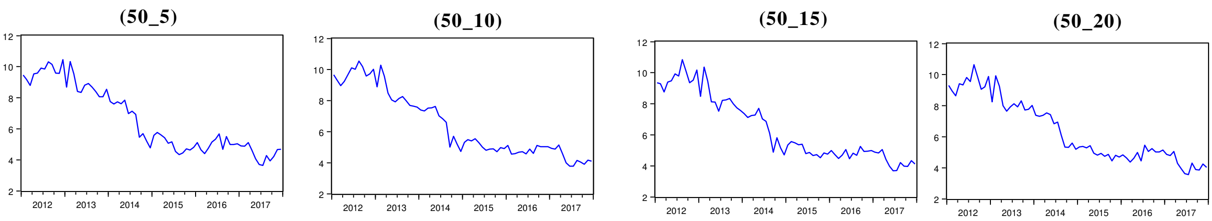
Core inflation	ECT	Standard Error	t-statistics	p-value	RMSE
CPI _ Excluding food	-0.147	0.077	-1.905	0.061	1.401
CPI _ Excluding energy	0.311	0.242	1.286	0.203	1.221
CPI _ Excluding food and energy	-0.132	0.078	-1.687	0.097	1.463
CPI_(50, 5)	-0.218	0.097	-2.251	0.028	0.303
CPI_(50,10)	-0.219	0.081	-2.461	0.017	0.288
CPI_(50,15)	-0.212	0.086	-2.474	0.026	0.271
CPI_(50,20)	-0.207	0.087	-2.366	0.021	0.222
CPI_(52.5,10)	-0.184	0.082	-2.241	0.029	0.252
CPI_(48,20)	-0.195	0.089	-2.192	0.032	0.284
CPI_(48.5,20)	-0.208	0.088	-2.379	0.021	0.219*

Figure 2: Graphical representation of different measure of Core Inflation

1. Conventional exclusion based measures



2. Symmetric Trimmed Mean Measure



3. Asymmetric Trimmed Mean Measure

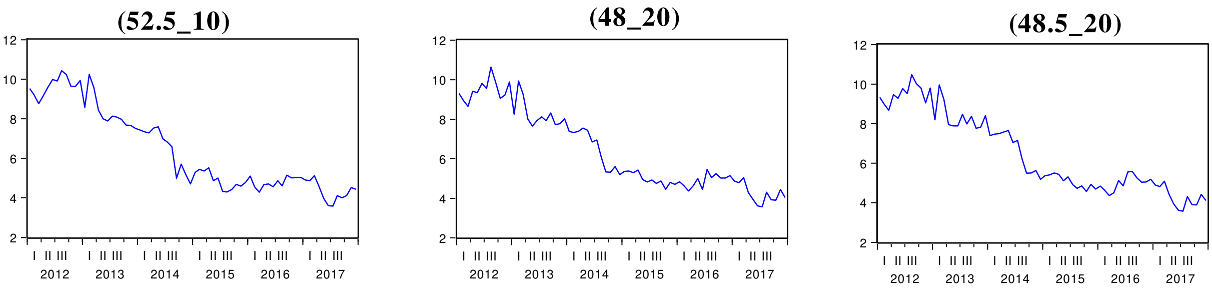


Figure 2; represents the different core inflation series calculated from conventional exclusion method, symmetric trim mean and asymmetric trim mean

Figure 3: Headline Inflation and Core Inflation (48.5, 20)

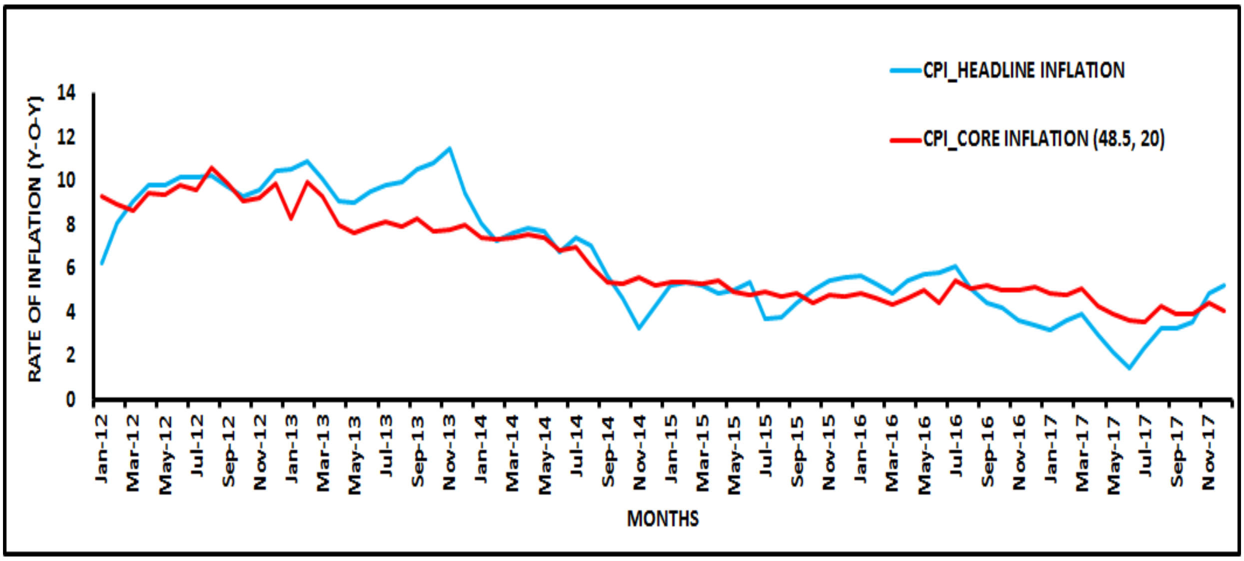


Figure 3; represents the best measure of core inflation calculated from asymmetric trim mean approach i.e. (48.5, 20) trimmed series of core inflation is considered as the best series, which can also be considered as a good trend for headline inflation.

4.3 Model Specification and Econometric Modelling

This section deals with the modelling to capture the dynamic effects of demand and supply shock on core inflation[2]. Macroeconomics indicators such as output gap (o^g) money growth (m^g) short-term interest rate or call money rates (I) real effective exchange rate (ex) are considered as demand shocks as because any changes in these indicators will directly affect the aggregated demand (AD) for an economy. On the other hand, fuel inflation (F_u) food inflation (F_O) and skewness-based inflation[3] (S_s) is considered as three alternatives supply shocks in the econometric modelling.

The theoretical understanding for modelling inflation can be considered from augmented Philips curve, where the expectation are formed adaptively. Additionally, inflation and output gap is inversely associated. A positive output gap i.e. when actual output is greater than the

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[2] Estimated Trimmed mean (48.5, 20) core inflation is used as a proxy for core inflation in the econometric modelling.

[3] Skewness based inflation or supply shock is calculated by differencing core inflation (calculated through asymmetric trim mean approach) from headline inflation.

potential output can lead to inflationary pressure in an economy and vice versa. Similarly, the role of shocks gained importance in predicting inflation during the 1970s. Gorden (1977; 1982) study extended the expected augmented Philips curve by incorporating the supply shocks and (Hallman, et al., 1989; 1991) develop the P-star model of inflation based on quantity theory of money, i.e., PY = MV. Considering the theoretical understanding, we have formulated three econometric modelling with respect to three different supply shock i.e. (S_s) (F_O) and (F_u).

MODEL 1: (Supply Shock - Skewness Based Inflation *(S_s)*)

$$\pi_t^c = \partial + \sum_{i=1}^{n} \alpha_i \pi_{t-i}^c + \sum_{j=0}^{n} b_j o_{t-j}^g + \sum_{k=0}^{n} c_k m_{t-k}^g + \sum_{l=0}^{n} d_l I_{t-l} + \sum_{q=0}^{n} f_q ex_{t-q} + \sum_{r=0}^{n} g_r S_{st-r} + u_{1t}$$

MODEL 2: (Supply Shock - Food Inflation (F_O))

$$\pi_t^c = \partial^* + \sum_{i=1}^{n} a^*{}_i \pi_{t-i}^c + \sum_{j=0}^{n} b^* o_{t-j}^g + \sum_{k=0}^{n} c^*{}_k m_{t-k}^g + \sum_{l=0}^{n} d^*{}_l I_{t-l} + \sum_{q=0}^{n} f^*{}_q ex_{t-q} + \sum_{r=0}^{n} g^*{}_r F_{O_{t-r}} + u_{2t}$$

MODEL 3: (Supply Shock - Fuel Inflation (F_u))

$$\pi_t^c = \partial^{**} + \sum_{i=1}^{n} a^{**}{}_i \pi_{t-i}^c + \sum_{k=0}^{n} b^{**}{}_k o_{t-k}^g \sum_{k=0}^{n} c^{**}{}_k m_{t-k}^g + \sum_{l=0}^{n} d^{**}{}_l I_{t-l} + \sum_{q=0}^{n} f^{**}{}_q ex_{t-q} + \sum_{r=0}^{n} g^{**}{}_r F_{u_{t-r}} + u_{3t}$$

The study uses linear Autoregressive Distributed Lag (ARDL)[4] Bound test procedure, originally introduced by (Pesaran and Shin, 1999) to estimate the impact of macroeconomic indicators on inflation. Linear Autoregressive Distributed Lag (ARDL) takes the form as;

$$y_t = C + \sum_{i=1}^{p} a_i \Delta y_{t-i} + \sum_{j=0}^{q} b_j \Delta x_{t-j} + \rho y_{t-1} + \propto x_{t-1} + \varepsilon_{t-1} + U_t$$

Where, y_t is the k × 1 vector of endogenous variables, x_t is the k × 1 vector of exogenous variables, ε_{t-1} is the error correction term, U_t is the white noise error term and a_i, b_j, $\rho, \propto$ are the parameters coefficients in the ARDL model. ARDL bound test is used to capture the dynamic effects of core inflation in the short run and long run. The bound test is based on F-statistics. It indicates the long run association among the macroeconomic variables only if the F-statistics is greater than the critical values of the upper bound i.e. I (0) in the ARDL bound test.

[4] ARDL bound test is convenient to use with a combination of stationary and non – stationary data (at level).

Section - V
Empirical Analysis

5.1 Stationarity Test

Table 5: ARDL Bound Test						
	Model 1		**Model 2**		**Model 3**	
F-statistics	15.969		12.477		16.531	
Level of significance	10%		5%		1%	
Critical Value Bounds	I (0) (2.26)	I (1) (3.45)	I (0) (2.62)	I (1) (3.79)	I (0) (3.41)	I (1) (4.68)

The unit root test is performed by ADF test for each time series data. The entire macroeconomic variable except for real interest rate and real effective exchange rate depreciation is stationary at level i.e. I (0), whereas all the other variables become stationary after first difference i.e. I (1).

Table 4: Stationarity Test

Variables	**With Intercept**		**With Intercept and Trend**	
	At level	**At first Difference**	**At level**	**At first Difference**
Core Inflation	0.711	0.000	0.098	0.000
Money Growth	0.707	0.000	0.180	0.000
Output Gap	0.159	0.040	0.409	0.036
Interest Rate	0.001	-	0.008	-
Real Exchange Rate	0.001	-	0.005	0.000
Skewness based inflation	0.090	0.000	0.081	0.000
Food Inflation	0.254	0.000	0.058	0.000
Fuel Inflation	0.391	0.000	0.047	0.000

Note: Figures denotes the p-value

5.2 Bound Testing Approach

ARDL model is best fitted with the combination of I (0) and I (1), therefore the parameters coefficient are estimated through this technique. Before proceeding with the ARDL techniques bound test is performed. In the entire three model, F- statistic is greater than the critical value of the upper bound, indicating the long run association of core inflation with the regressors incorporated in the entire model.

5.3 Dynamic Effects of the macroeconomic variables on core inflation

Short –Run Dynamic Effects

The speed of adjustment coefficient, i.e. the Error Correction Term (ECT) reinstates equilibrium in the dynamic model has a negative sign and statistically significant ensuring long-run equilibrium can be attained. Akai Information Criteria (AIC) is used to select optimal lag length in the entire three model. In model 1, 2 and 3, we have taken two lag values of core inflation, whereas all other variables are taken without their lags, except for the model 2, where only one lag value of food inflation is considered.

Table 6; represents the short-run dynamics of the macroeconomics variables on core inflation. It is empirically evidence that the past values of core inflation has a positive and significant effect on the present core inflation. Additionally, the demand shock variables, that is $(o^g\ )\ and\ (m^g\ )$ show positive and significance effect on core inflation, whereas (ex) and *(I)* show negative association with the core inflation in the short run. Similarly, three supply shocks i.e. (S_s) (F_O) and (F_u).have shown positive and significant relationship with the core inflation in the short run.

Moreover, while considering the magnitude of response of the demand shock, such as, outgap and monetary variables (money growth, interest rate and exchange rate) it is observed that real output gap has the higher impact on core inflation as compare to monetary variables in the entire three model. One percentage change in output gap will create an inflationary pressure by 27. 9 percentage in model one, 28.2 percentage in model two and 30.7 percentage in model three respectively.

With respect to supply shocks, the magnitude of response of core inflation to one percentage change in skewness based inflation ((S_{st}) is (42.8 percentage), fuel inflation (F_{ut}) is (6.8 percentage) and food inflation $\{(F_{Ot}\ \ and\ F_{Ot-1})\}$ is (6.8 and 16.1 percentage) respectively. The magnitude of response of the supply shock i.e. (S_{st}) is high as compared to (F_{ut}) and (F_{ot}).

Overall, it is observed from the short run dynamics that both demand and supply shock have significant effect on the core inflation. The F-statistics in the entire three model is significant at one percent level of significance. Similarly, the predictive ability of the entire three model is performed through Room Mean Square Error (RMSE) is lies between (0 to 0.5) for the entire three model

Table 6: ARDL (Short – Run Coefficients)

Variable	Model 1			Model 2			Model 3		
	ARDL MODEL SELECTION (2,0,0,0,0,0)			ARDL MODEL SELECTION (2,0,0,0,0,1)			ARDL MODEL SELECTION (2,0,0,0,0,0)		
	Coeffi	S.E	T-Stat	Coeffi	S.E	T-Stat	Coeffi	S.E	T-Stat
Constant	-0.087	0.045	-1.919	-0.105	0.050	-2.082	-0.123	0.052	-2.366
$(ln)\Delta\pi^{c}_{t-1}$	0.297	0.099	2.992	0.389	0.120	3.251	0.416	0.114	3.637
$(ln)\Delta\pi^{c}_{t-2}$	0.225	0.091	2.469	0.281	0.119	2.359	0.226	0.110	2.054
Δo^{g}_{t}	0.279	0.134	2.076	0.282	0.129	2.182	0.307	0.142	2.166
Δm^{g}_{t}	0.072	0.034	2.117	0.048	0.015	3.201	0.025	0.015	1.666
ΔI_{t}	-0.415	0.079	-5.225	-0.217	0.079	-2.750	-0.160	0.068	-2.364
Δex_{t}	-0.125	0.054	-2.314	-0.154	0.052	-2.961	-0.187	0.054	-3.462
ΔS_{st}	0.428	0.096	4.448						
ΔF_{Ot}				0.068	0.066	1.034			
ΔF_{Ot-1}				0.161	0.074	2.173			
ΔF_{Ut}							0.068	0.021	3.238
ECT (-1)	-0.552	0.161	-3.428	-0.670	0.197	-3.401	-0.642	0.188	-3.414
R – square	0.683			0.554			0.582		
Adjusted	0.590			0.437			0.448		
D-W stat	1.955			1.979			1.997		
F-statistics	7.329			4.708			4.345		
RMSE	0.312			0.384			0.388		

Note: variables are significant at 1 and 5 percent level of significance.
Source: Author’s calculation.

Long–Run Dynamic Effects

The long run dynamic effects of the macroeconomics variables on core inflation indicates that the impact of output gap on the core inflation is negative in the long run indicating that the gap between actual output and the potential output get minimizes in the long - run. However, Money growth has a positive but insignificant effect on the core inflation in the long indicating that there is no long run effect of money growth. Similarly, interest rate also keep inflation low in the long - run. The monetary variables such as money growth and interest rate keep inflation low by targeting its policy rates, thus indicating effectiveness of the monetary policy in India. Additionally, it is also empirically observed that there persist a long run impact of skewness based supply shock on the core inflation in India, where as food inflation and fuel inflation does not seems to effect core inflation in the long - run.

Table 7: ARDL Estimates (long – Run Coefficients)

Variable	Model 1				Model 2				Model 3			
	1	*2*	*3*	*4*	*1*	*2*	*3*	*4*	*1*	*2*	*3*	*4*
Constant	-0.057	0.028	-2.029	0.048	-0.063	0.029	-2.159	0.035	-0.075	0.030	-2.506	0.016
O_t^g	-1.012	0.944	-1.073	0.289	-1.049	0.428	-2.450	0.018	0.438	0.994	0.440	0.662
m_t^g	0.070	0.043	1.630	0.109	0.022	0.023	0.967	0.338	0.078	0.065	1.207	0.233
I_t	-0.273	0.067	-4.043	0.000	-0.208	0.071	-2.910	0.005	-0.098	0.045	-2.178	0.034
ex_t	-0.452	0.252	-1.793	0.066	-0.256	0.089	-2.876	0.036	-0.259	0.254	-1.019	0.068
S_{st}	0.281	0.076	3.704	0.001					0.041	0.054	0.763	0.449
F_{Ot}					0.055	0.068	0.820	0.416				
F_{Ut}									0.438	0.994	0.440	0.662

NOTE :(1, 2, 3, 4) denotes coefficient value, standard error, T- Statistics and P-value

5.4 Residual Diagnostic

For testing serial correlation in the error term, Breusch –Godfrey Serial Correlation LM test is applied. It assumes the null hypothesis of no serial correlation in errors terms. There is no problem of serial correlation in the entire three model. Breusch-Pagan-Godfrey-Test is used to test heteroscedasticity in the data. The test results suggest that residuals are homoscedastic. Jarque – Bera test statistics is used to test the normal distribution of data. The results indicate that the residuals are normally distributed in the entire three model.

Table 8: Residual Diagnostic

Test-Statistics	Model 1	Model 2	Model 3
Jarque – Bera Statistics	2.264	0.058	5.004
Normality Test	(0.322)	(0.971)	(0.813)
`Breusch-Godfrey	0.334	0.106	0.049
Serial Correlation	(0.716)	(0.899)	(0.951)
Breusch-Pagan (BP) test	0.707	0.376	0.528
Heteroscedasticity test	(0.915)	(0.784)	(0.803)

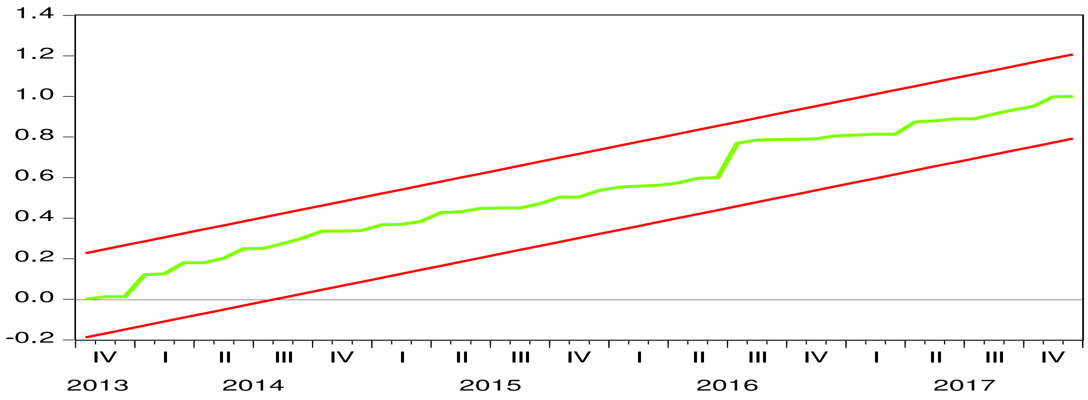
Note :

a. *Breusch-Godfrey Serial Correlation LM Test is based on F-statistics*
b. *Breusch-Pagan (BP) test of* heteroscedasticity *is based on Chi – square Test.*
c. *Figures in the parenthesis denotes the p-value.*

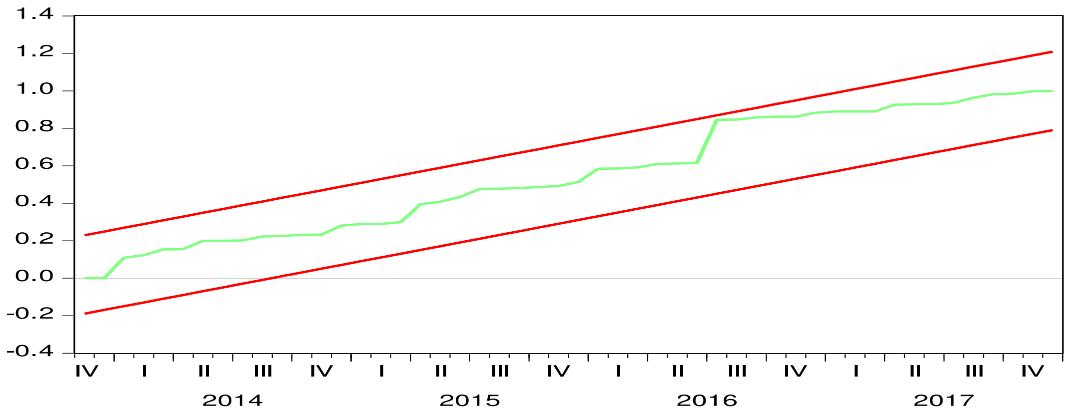
5.6 Stability of the coefficient (CUSUM Square Test)

Cumulative sum of square test indicates the stability of the coefficients at 5 percent level of significance in the entire three model.

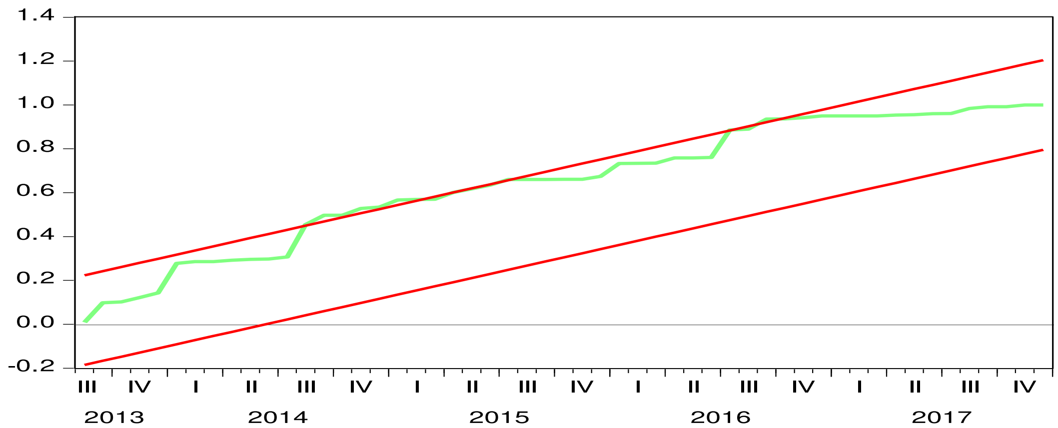
Model -1



Model - 2



Model - 3



Section - VI
Conclusion

The aim of the study is to empirically analyse and capture the dynamic effects of demand and supply shocks on core inflation in India. To calculate core inflation from headline inflation, asymmetric trimmed mean measure is used, which indicates that (48.5, 20) trimmed series as the best measure of core inflation and can be used as a good trend for the underlying headline inflation. The present study has also calculated core inflation through different method that conventional exclusion based measure and symmetric trim mean method. Among all the three methods, asymmetric trim mean approach has shown a strong correlation with the headline inflation.

Further, ARDL Bound testing approach is used to capture the dynamic behaviour of the macroeconomics variables towards the core inflation The evidence from empirical investigation suggest that there is a significant impact of demand and supply shock on core inflation. The response of core inflation to demand shock is high in case output gap as compared to monetary variables, indicating the higher impact of non-monetary factor on core inflation in India. Similarly, the response of skewness-based inflation on core inflation is high as compare to food and fuel inflation in India.

Overall, it can be concluded that the paper has attempted on the empirical analysis of core inflation, which is estimated through both statistical and econometric analysis and can be used as a good trend for the underlying inflation while taking decision on policy forecasting.

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