

Sharma, Naresh Kumar; Bicchal, Motilal

Article

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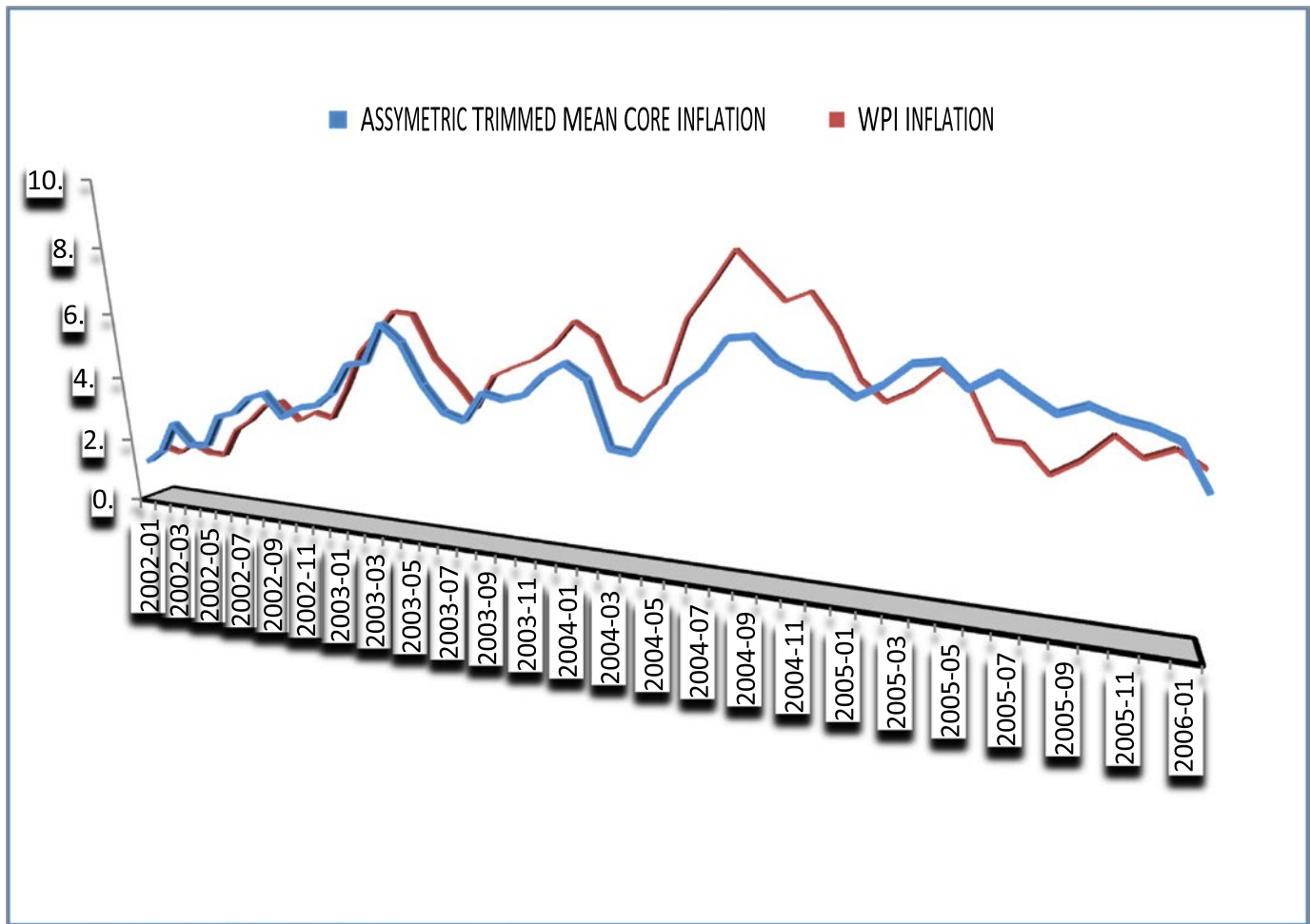
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*Corresponding author: Motilal
Bicchal, Department of Economics,
Sangameshwar College, Solapur
413005, India
E-mail: bmotilal@gmail.com

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Measuring core inflation in India: An asymmetric trimmed mean approach

Naresh Kumar Sharma¹ and Motilal Bicchal^{2*}

Abstract: The paper seeks to obtain an optimal asymmetric trimmed mean-based core inflation measure in the class of trimmed mean measures when the distribution of price changes is leptokurtic and skewed to the right for any given period. Several estimators based on asymmetric trimmed mean approach are constructed and estimates generated by use of these estimators are evaluated on the basis of certain established empirical criteria. The paper also provides the method of trimmed mean expression “in terms of percentile score.” This study uses 69 monthly price indices which are constituent components of Wholesale Price Index for the period, April 1994 to April 2009, with 1993–1994 as the base year. Results of the study indicate that an optimally trimmed estimator is found when we trim 29.5% from the left-hand tail and 20.5% from the right-hand tail of the distribution of price changes.

Subjects: Statistics for Business, Finance & Economics; Macroeconomics; Monetary Economics; Econometrics

Keywords: core inflation; inflation; asymmetric trimmed mean; Wholesale Price Index

1. Introduction

Among various approaches to measuring core inflation discussed in the literature, the limited influence estimator (LIE) approach has gained considerable attention. There are two kinds of measures based on the LIE approach: the conventional symmetric trimmed mean measures and the asymmetric trimmed mean measures. Use of symmetric trimmed mean and median as a core inflation measure is

ABOUT THE AUTHORS



Motilal Bicchal

Naresh Kumar Sharma is a professor in the School of Economics, University of Hyderabad, India. After a BTech in Mechanical Engineering from IIT Kanpur, he obtained his PhD in Economics from the Indian Statistical Institute (Delhi Center). He holds the position of the coordinator of the Programme for Gandhian Economic Thought at the University of Hyderabad. His other research interests are in the areas of development economics and economic theory.

Motilal Bicchal has obtained his PhD in Economics from the University of Hyderabad, India, under the supervision of Prof. Naresh Kumar Sharma and Prof. Bandi Kamaiah. This paper forms part of his PhD work. He is an assistant professor at the Department of Economics, Sangameshwar College, Solapur, India.

PUBLIC INTEREST STATEMENT

Core inflation is a concept that focuses on capturing the underlying inflationary tendency of an economy by trying to eliminate the transient (or noise) components in observed inflation. The objective of the paper is to find an optimal asymmetric trimmed mean-based core inflation measure for India. It is argued that asymmetric trimming procedures are more appropriate when the distribution of price changes itself is skewed and leptokurtic. The paper computes several trimmed mean measures and subsequently evaluates them according to a set of prespecified empirical criteria, in order to find the best measure in a class of the trimmed means measures. Among the several trimmed means, an asymmetric trimmed means series is seen to satisfy all the necessary evaluation criteria of core inflation. Therefore, it is presented as a suitable measure of core inflation indicator for India.

justified on the grounds of its efficiency when the statistical distribution of price changes is symmetric though leptokurtic. However, when distribution of price changes is positively skewed,¹ symmetric trimmed mean estimators are biased estimators of measured inflation. For eliminating this systematic bias, Roger (1997) pioneered the asymmetric trimmed mean approach to measure core inflation. Subsequently, this approach has been applied by many researchers in various countries.

Mohanty, Rath, and Ramaiah (2000) were the first to construct a LIE-based core inflation measure for India. This as well as some other studies that have used LIE method for measuring core inflation for India, computed symmetric trimmed means. However, given skewness in the distribution of price changes (as also observed with the Indian data), a symmetric trimmed mean estimator systematically underestimates the headline inflation. Consequently, the symmetric trimmed mean may not be a very useful estimator of underlying trend inflation under such circumstances.

The present paper is aimed at finding optimal trimmed mean using asymmetric trimmed mean as an estimator of core inflation for India. Several estimators based on asymmetric trimmed mean approach are constructed. Estimates generated by these are evaluated on the basis of conditions set out in Marques, Neves, and Sarmento (2000) in order to find the best asymmetric trimmed mean-core inflation measure for India.

The paper is organized as follows: Section 2 provides a brief overview of the literature on LIE as a core inflation measure. Section 3 describes methodology used for computing cross-sectional distributions of price changes, methods of computing trimmed mean measures, and empirical criteria for finding optimal trimmed means. Section 4 deals with the results. It ends with some comparisons between symmetric and asymmetric trimmed mean core inflation estimates for India. Section 5 offers some concluding observations.

2. LIE: an overview

The LIE is an alternative approach for conventional ex-food and ex-energy core inflation measures. The basic idea of the LIE approach is that it excludes certain components from cross-section distribution of price changes in each period on the basis of their 'contribution to noise' in measured inflation.² It systematically excludes a percentage from each tail of the cross-section distribution of price changes and takes the weighted average of price changes for the rest of components in the aggregate price index. This process is followed in each period so that a component that was extreme or an outlier in one period may or may not be an outlier in some or all of subsequent periods.

The use of LIE for estimating core inflation is supported in both economic and statistical senses. The economic arguments are generally based on New-Keynesian models of price-setting behavior in the presence of adjustment costs, while in statistical terms, it is argued that LIE in the presence of non-normality in the distribution of price changes is a best estimator of central tendency.

Bryan, Cecchetti, and Wiggins (1997) and Roger (1997) observed that a symmetric trimmed mean or median is a more efficient estimator of core inflation if the distribution of price changes is symmetric but exhibits high *kurtosis*. However, if the price distribution is positively skewed, all symmetric trimmed means as limited-influence estimators (including median) are *systematically downward* biased estimators of measured inflation. For eliminating this bias, Roger (1997) proposed an asymmetric trimmed mean approach i.e., locating the trimming center on higher than 50th percentile. A number of researchers have found cross-section inflation distribution to be skewed. Some instance are: Kearns (1998) for Australia; Meyler (1999) for Ireland; Bakhshi and Yates (1999) for England; Aucremanne (2000) for Belgium; and Marques and Mota (2000) for Portugal. They therefore followed asymmetric trimmed mean approach pioneered by Roger (1997). It may be noted that Kearns (1998) and Meyler (1999) used RMSE-reference trend evaluation procedure (due to Bryan et al. 1997) to determine the optimal trim and the asymmetry of the trimming procedure. Kearns (1998) computed asymmetric trimmed mean with centers lying between the 40th and 60th percentiles, and Meyler (1999) with centers lying between

the 40th and the 70th percentiles. They then selected optimal asymmetric trimmed mean that minimized the deviation gap measured by RMSE or MAD relative to a reference trend series—such as a moving average of measured inflation. Aucremanne (2000) computed trimmed means by choosing the centers of trimming scheme between 50th and 60th percentiles and then, as a first step, he selected those trimmed means for which the null hypothesis of normality of the underlying distribution was not rejected according to Bera–Jarque statistic. Among these, he then selected the optimum trimmed mean as the one that minimizes the average absolute error relative to the inflation rate. Marques et al. (2000), on the other hand, criticized the use of benchmark-reference trend series as a device to search for the optimal trimmed mean series. They argued that trend reference measure such as moving average of inflation does not guarantee that it is the best proxy for ‘true trend’ of inflation series for several reasons. Empirical findings of Aucremanne (2000) and Dolmas (2005) show that the optimal trim varies with smoothness of moving average and also different proxy reference measures for trend series.

Marques et al. (2000) proposed a new set of criteria to find the optimal trimmed mean series. This consists of three evaluation criteria of core inflation as a basis to determine the optimal trimmed mean series. We shall discuss these criteria in Section 3.3.

The assumption of time-invariant optimal trim, implicit in several of the earlier discussions, is open to question and scrutiny. Since trimming parameter depends on the values of the moments of the cross-sectional distribution, the optimal trim may change from one period to another period with changes in the sample distribution of price changes. Therefore, robustness associated with the optimal trim (used to obtain the best trimmed mean as a measure of core inflation) needs to be established. Moreover, trimming parameters may also be sensitive to changes in the degree of disaggregating of price components. One possible solution to the former is to check the asymmetric behavior of price distribution over sample period. This can be done by testing the stationarity properties of the mean percentile.

3. Data and methods

3.1. Cross-sectional distribution of price changes for India

The purpose of this section is to examine the key characteristics of the cross-sectional distribution of prices changes in the WPI and their implications for computing core inflation measures for India.

We use the monthly price indices for 69 commodity groups which are constituent components of WPI. The period covered is from April 1994 to April 2009, with 1993–1994 as the base year. Despite various shortcomings of WPI index, we focus on the WPI mainly because the Reserve Bank of India (RBI) bases its definition of price stability in terms of this price index. The weights and data for each component of WPI index are collected from the RBI data warehouse website.

The inflation rate of each individual component (commodity group) is the rate of change of its individual price index. These in turn provide a cross-sectional distribution of price changes at a given point of time. To circumvent the seasonal effect on individual prices, we use year on year inflation rates. Subsequently, the moments of cross-sectional distribution of price changes are calculated by the time-varying weights.

Let P_t stand for price level in period t , which is defined as follows:

$$P_t = \sum_{i=1}^n w_{i0} P_{it} \quad (1)$$

where n is the number of the commodity groups in the price index, P_{it} is the price index of the commodity group i in period t , and w_{i0} is the weight of good i in the price index fixed for a base year, with

$$\sum_{i=1}^n w_{i0} = 1$$

With monthly time series data on prices, inflation for each commodity group i is defined as,

$$\pi_{it} = \left(\frac{P_{it} - P_{i,t-12}}{P_{i,t-12}} \right) \times 100$$

Inflation for all commodities, likewise, is defined as:

$$\begin{aligned} \pi_t &= \left(\frac{P_t - P_{t-12}}{P_{t-12}} \right) \times 100 = \sum_{i=1}^n w_{i0} \frac{(P_{it} - P_{i,t-12})}{P_{t-12}} \times 100 \\ &= \sum_{i=1}^n w_{i0} \frac{(P_{it} - P_{i,t-12})}{P_{i,t-12}} \times \frac{P_{i,t-12}}{P_{t-12}} \times 100 \end{aligned}$$

Thus,

$$\pi_t = \sum_{i=1}^n w_{it} \pi_{it} \quad (2)$$

where $w_{it} = w_{i0} \cdot \frac{P_{i,t-12}}{P_{t-12}}$ is the time-varying weight of the commodity group i for the month t .

The K th weighted central moment of a cross-section distribution, at time t , is then defined as:

$$m_{kt} = \sum_{i=1}^n w_{it} (\pi_{it} - \pi_t)^k \quad (3)$$

In particular, the skewness (S_t) and kurtosis (K_t) can be expressed as:

$$S_t = m_{3t} / (m_{2t})^{3/2} \quad (4)$$

$$K_t = \left\{ m_{4t} / (m_{2t})^2 \right\} - 3 \quad (5)$$

The coefficient of skewness (S_t) for a distribution is a measure of asymmetry of the distribution of the series around its mean. A positive value of skewness coefficient implies that the distribution is skewed to the right (and vice versa). The coefficient of kurtosis (K_t) measures “excess” kurtosis relative to the normal distribution. Any value above zero indicates leptokurtic distribution of prices changes.

Figure 1 plots the coefficients of skewness (S_t). This demonstrates that over the sample period the coefficient of skewness is mostly positive: it is positive for 150 months out of 169. This finding suggests that there is persistent positive skewness in the distribution of WPI price changes. The dotted line in the figure is the average value of skewness which is equal to 1.34. This finding of positive skewness is consistent with other empirical evidence from various countries—for instant, skewness was found to be 0.70 for New Zealand by Kearns (1998), for Portugal it was 0.83 (Marques & Mota, 2000), and for Ukraine 1.23 (Wozniak & Mykhaylychenko, 2005), etc.

Another measure of asymmetry of the distribution is the mean percentile. The mean percentile is nothing but percentile score of the sample mean of the distribution. For a positively skewed distribution, the value of mean percentile will be greater than 50. Figure 2 plots the empirical mean percentile for the price change distribution over the sample period. The result shows that the mean percentiles lie above 50th percentile in 153 times out of the 169 monthly distributions, providing further evidence of chronic positive skewness in the distribution of price changes. The dotted line in Figure 2 is the average value of mean percentile scores or average mean percentile, which is obtained by averaging the monthly empirical mean percentiles over the sample period. For the sample period, the average mean percentile is at 57.85 as shown by dotted line in the figure.

Figure 1. Skewness and average value of skewness.

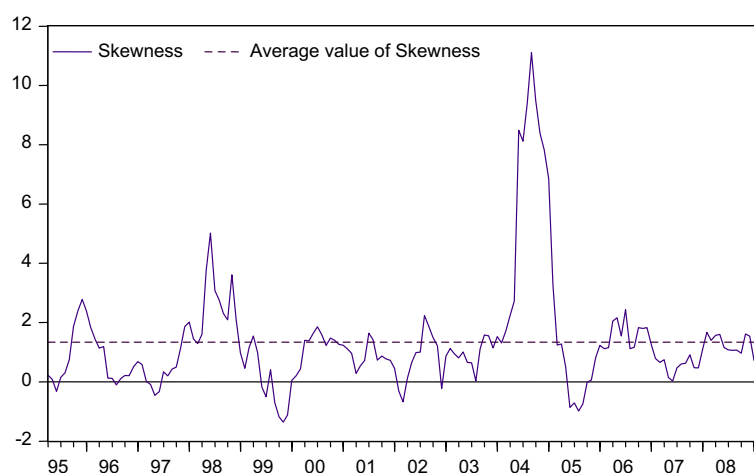


Figure 2. Mean percentile and average mean percentile.

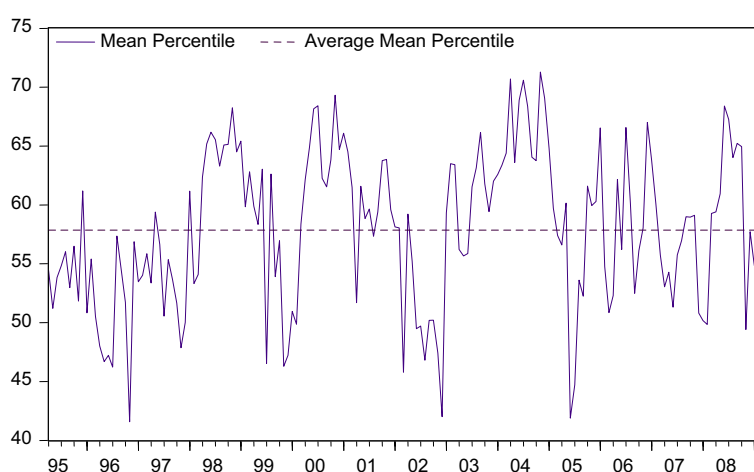
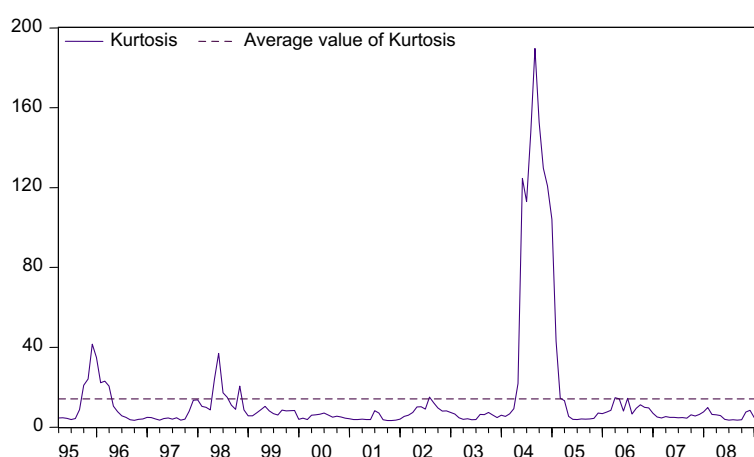


Figure 3. Kurtosis and average value of kurtosis.



Finally, Figure 3 plots coefficient of kurtosis (K_t) and the respective average value over the sample period. The average value of kurtosis is 14.18, indicating that the empirical distribution of the price changes is strongly leptokurtic. The coefficient of kurtosis for entire sample distribution is always

greater than zero. There is sharp peak for period 2004–2005. For most other years (barring 1995 and 1998), the distribution are mildly leptokurtic, as can be clearly seen in the figure.

Overall, the distribution of price changes for India is seen to be leptokurtic and persistently right skewed. This characteristic of the WPI data is consistence with the findings for other countries and time periods. This result is suggestive of suitability of asymmetric trimmed mean approach to Indian data for deriving core inflation measures.

3.2. Asymmetric trimmed mean inflation estimators

This section computes various trimmed mean measures for India and subsequently evaluates them according to prespecified criteria to find an optimal trimmed mean core inflation measure for India.

Before going on to compute trimmed means, it is pertinent to address the issue of the behavior of asymmetry (skewness) of distribution of price changes over time. This can be checked by testing for the stationarity of the mean percentile. The second row of Table 1 results of unit root test for mean percentile. The unit root test statistics show that mean percentile is stationary in the sample period. The basic idea of testing stationarity of mean percentile is that if mean percentile is stationary then there is no problem of time variability of skewnees (Marques & Mota, 2000). Consequently, the degree of asymmetry can be assumed as constant.

A trimmed mean is computed by choosing a value of the left trim and a value of the right trim for a given distribution of price changes. One way of representing such a distribution for any given period is to express all commodity groups according to their percentile scores (ranging from 0 to 100). Now any trim scheme can be represented by a center (c) and a trim (α) as follows: suppose left trim is at l percentile and the right trim is at r percentile, i.e. the range of price changes to be included is given by percentile interval $[l, r]$. Then, the center $c = \frac{l+r}{2}$ and trim $\alpha = 50 - \left(\frac{r-l}{2}\right)$, and we represent it as $TM\left(\frac{l+r}{2}, 50 - \left(\frac{r-l}{2}\right)\right)$. Thus a $TM(c, \alpha)$ represent the percentile interval, $[(c + \alpha - 50), (c - \alpha + 50)]$. When $c = 50$, we have a case of symmetric trim. $TM(50, 10)$, for example, denotes 10% trimmed mean centered on the 50th percentile. It is short for the percentile interval $[40, 60]$, which is nothing but trimming symmetrically 10% of the smallest and 10% of the largest price changes or 10% from each tail of the price change distribution. On the other hand, a $TM(57, 15)$ denotes 15% trimmed mean centered on the 57th percentile, and it gives the percentile interval of $[22, 92]$, which is obtained by asymmetrically trimming the smallest 22% and the largest 8% price changes. Likewise a $TM(45, 20)$ represents interval $[15, 75]$, but, since distributions of price changes are positively skewed on average, we ignore the cases like the last example. This method of representation has the advantage of explicitly showing where the percentile interval (used for calculating core inflation) is centered and what the average trimming from the two tails is.

Trims (α 's) are set at intervals of five percentile points starting from 10 percentile to 45 percentile. We choose all centers (c 's) between 50th percentile and 60th percentile at the interval of 0.5 percentile points. Thus, a total 168 time series of trimmed means are computed over the sample period

Table 1. Unit root tests for WPI inflation and mean percentile

	ADF test	PP test	KPSS test
WPI inflation	-3.28(-2.88)	-3.79(-3.47)	0.11(0.74)
Mean percentile	-4.60(-3.47)	-6.34(-3.47)	0.21(0.35)

Notes: Values in parentheses are critical values of test statistics with intercept. Lag length are chosen basis on SIC.

With 5% significance level, the null hypothesis of ADF unit root for WPI inflation can be rejected. With 1% significance level, the null hypothesis of PP unit root for WPI inflation can be rejected. With 10% significance level, the null hypothesis of KPSS stationary test for WPI inflation cannot be rejected. With 1% significance level, the null hypothesis of ADF and PP unit root for mean percentile can be rejected and with 10% significance level, the null hypothesis of KPSS stationary test for mean percentile cannot be rejected.

1995:04 to 2009:04. Note the symmetric trimmed means are a special case in this procedure, when we choose $c = 50$.

3.3. Criteria for finding optimal asymmetric trimmed means

In order to find an asymmetric trimmed mean as an optimal core inflation measure, Marques et al. (2000) introduced three econometric evaluation criteria. Those trimmed means that pass these three evaluation tests possess some nice econometric properties, and hence can be used as useful core inflation measures. The three tests are briefly discussed below. We shall represent the headline inflation by π_t , and a core inflation measure by π_t^* .

Test 1: unbiasedness property of core inflation:

If headline inflation, π_t is $I(1)$, then core inflation, π_t^* should be $I(1)$ as well and both of them should be co-integrated with coefficient 1, i.e. $\varepsilon_t = (\pi_t - \pi_t^*)$ should be a stationary variable with zero mean. If headline inflation, π_t is $I(0)$, then it is sufficient if $E(\pi_t - \pi_t^*) = 0$ holds.

The first row of Table 1 shows that headline inflation in India is stationary, $I(0)$. Therefore, headline inflation cannot be co-integrated with core inflation. In such case, it is sufficient that $E(\pi_t - \pi_t^*) = 0$ i.e. headline and core inflation series should have equal unconditional mean. We test this condition by restriction $\alpha_0 = 0; \beta_1 = 1$ in the static regression:

$$\pi_t = \alpha_0 + \beta_1 \pi_t^* + u_t \quad (6)$$

Core inflation measures that pass this test are unbiased estimators. The OLS estimation of regression (6) exhibits strong autocorrelation therefore the standard error for regressions are computed using Newey–West (1987) procedure with four lags.

Test 2: attractor property of core inflation:

This is based on the error correction mechanism, which is given by $z_{t-1} = (\pi_{t-1} - \pi_{t-1}^*)$ for $\Delta\pi_t$,

$$\Delta\pi_t = \sum_{j=1}^m \alpha_j \Delta\pi_{t-j} + \sum_{j=1}^n \beta_j \Delta\pi_{t-j}^* - \gamma (\pi_{t-1} - \pi_{t-1}^*) + \varepsilon_t \quad (7)$$

where m and n represent number of lags for headline inflation and core inflation respectively.

This second condition implies that core inflation, π_t^* , is an attractor of the headline inflation, π_t , and requires an error-correction mechanism that describes the long-term causality relationship from core to headline. The condition is thus to test attractor property of core inflation by testing the null hypothesis of ‘no attraction’, $\gamma = 0$, using t -test statistic. The practical question to be addressed in the estimation of Equation 7 is how to select the appropriate number of lags m and n . In this study, the selection of the number of lags is based on Schwarz Information Criterion (SIC).

Test 3: exogenous property of core inflation:

π_t^* should be strongly exogenous for the parameters in Equation 7. This implies that in the error correction model for π_t^* :

$$\Delta\pi_t^* = \sum_{j=1}^r \delta_j \Delta\pi_{t-j}^* + \sum_{j=1}^s \theta_j \Delta\pi_{t-j} - \lambda (\pi_{t-1}^* - \pi_{t-1}) + \eta_t \quad (8)$$

and the hypothesis $\lambda = \theta_1 = \dots = \theta_s = 0$ should be accepted. In the above equation, r and s represent number of lags for core inflation and headline inflation, respectively.

This third condition guarantees that the movement in core inflation, $\Delta\pi_t^*$, is not determined by past headline inflation, $\Delta\pi_{t-j}$. As in Marques and Mota (2000), we test both for weak exogeneity ($\lambda = 0$) and strong exogeneity ($\lambda = \theta_1 = \dots = \theta_s = 0$) in the above equation. We again use SIC to select the number of lags.

4. Results and discussion

This section evaluates and discusses the results of three econometric tests as outlined in the previous section. Table 2 reports the results of test for the unbiasedness property of core inflation. It shows the OLS results for p -values from F -statistics for 168 trimmed means. The results indicate that among 168 trimmed means, 43 pass this test, suggesting that these 43 trimmed are unbiased trimmed mean measures. It may be noted that all these 43 trimmed means are asymmetric trimmed means.

Table 2. Test 1-unbiased property of core inflation

Trimmed means	p -values	Trimmed means	p -values	Trimmed means	p -values
TM(50, 45)	0.00	TM(57, 45)	0.00	TM(53.5, 45)	0.00
TM(50, 40)	0.00	TM(57, 40)	0.00	TM(53.5, 40)	0.00
TM(50, 35)	0.00	TM(57, 35)	0.00	TM(53.5, 35)	0.50*
TM(50, 30)	0.00	TM(57, 30)	0.00	TM(53.5, 30)	0.20*
TM(50, 25)	0.00	TM(57, 25)	0.03	TM(53.5, 25)	0.01
TM(50, 20)	0.00	TM(57, 20)	0.57*	TM(53.5, 20)	0.00
TM(50, 15)	0.00	TM(57, 15)	0.83*	TM(53.5, 15)	0.00
TM(50, 10)	0.00	TM(57, 10)	0.42*	TM(53.5, 10)	0.00
TM(51, 45)	0.16*	TM(58, 45)	0.00	TM(54.5, 45)	0.00
TM(51, 40)	0.00	TM(58, 40)	0.00	TM(54.5, 40)	0.00
TM(51, 35)	0.00	TM(58, 35)	0.00	TM(54.5, 35)	0.03
TM(51, 30)	0.00	TM(58, 30)	0.00	TM(54.5, 30)	0.66*
TM(51, 25)	0.00	TM(58, 25)	0.00	TM(54.5, 25)	0.23*
TM(51, 20)	0.00	TM(58, 20)	0.06*	TM(54.5, 20)	0.03
TM(51, 15)	0.00	TM(58, 15)	0.65*	TM(54.5, 15)	0.00
TM(51, 10)	0.00	TM(58, 10)	0.97*	TM(54.5, 10)	0.00
TM(52, 45)	0.00	TM(59, 45)	0.00	TM(55.5, 45)	0.00
TM(52, 40)	0.22*	TM(59, 40)	0.00	TM(55.5, 40)	0.00
TM(52, 35)	0.02	TM(59, 35)	0.00	TM(55.5, 35)	0.00
TM(52, 30)	0.00	TM(59, 30)	0.00	TM(55.5, 30)	0.11*
TM(52, 25)	0.00	TM(59, 25)	0.00	TM(55.5, 25)	0.70*
TM(52, 20)	0.00	TM(59, 20)	0.00	TM(55.5, 20)	0.34*
TM(52, 15)	0.00	TM(59, 15)	0.09*	TM(55.5, 15)	0.08*
TM(52, 10)	0.00	TM(59, 10)	0.64*	TM(55.5, 10)	0.02
TM(53, 45)	0.00	TM(60, 45)	0.00	TM(56.5, 45)	0.00
TM(53, 40)	0.03	TM(60, 40)	0.00	TM(56.5, 40)	0.00
TM(53, 35)	0.45*	TM(60, 35)	0.00	TM(56.5, 35)	0.00
TM(53, 30)	0.04	TM(60, 30)	0.00	TM(56.5, 30)	0.00
TM(53, 25)	0.00	TM(60, 25)	0.00	TM(56.5, 25)	0.18*
TM(53, 20)	0.00	TM(60, 20)	0.00	TM(56.5, 20)	0.78*
TM(53, 15)	0.00	TM(60, 15)	0.00	TM(56.5, 15)	0.53*
TM(53, 10)	0.00	TM(60, 10)	0.09*	TM(56.5, 10)	0.18*

(Continued)

Table 2. (Continued)

Trimmed means	p-values	Trimmed means	p-values	Trimmed means	p-values
TM(54, 45)	0.00	TM(50.5, 45)	0.00	TM(57.5, 45)	0.00
TM(54, 40)	0.00	TM(50.5, 40)	0.00	TM(57.5, 40)	0.00
TM(54, 35)	0.20*	TM(50.5, 35)	0.00	TM(57.5, 35)	0.00
TM(54, 30)	0.51*	TM(50.5, 30)	0.00	TM(57.5, 30)	0.00
TM(54, 25)	0.06*	TM(50.5, 25)	0.00	TM(57.5, 25)	0.00
TM(54, 20)	0.00	TM(50.5, 20)	0.00	TM(57.5, 20)	0.24*
TM(54, 15)	0.00	TM(50.5, 15)	0.00	TM(57.5, 15)	0.90*
TM(54, 10)	0.00	TM(50.5, 10)	0.00	TM(57.5, 10)	0.74*
TM(55, 45)	0.00	TM(51.5, 45)	0.01	TM(58.5, 45)	0.00
TM(55, 40)	0.00	TM(51.5, 40)	0.05*	TM(58.5, 40)	0.00
TM(55, 35)	0.00	TM(51.5, 35)	0.00	TM(58.5, 35)	0.00
TM(55, 30)	0.41*	TM(51.5, 30)	0.00	TM(58.5, 30)	0.00
TM(55, 25)	0.54*	TM(51.5, 25)	0.00	TM(58.5, 25)	0.00
TM(55, 20)	0.12*	TM(51.5, 20)	0.00	TM(58.5, 20)	0.01
TM(55, 15)	0.02	TM(51.5, 15)	0.00	TM(58.5, 15)	0.30*
TM(55, 10)	0.00	TM(51.5, 10)	0.00	TM(58.5, 10)	0.94*
TM(56, 45)	0.00	TM(52.5, 45)	0.00	TM(59.5, 45)	0.00
TM(56, 40)	0.00	TM(52.5, 40)	0.19*	TM(59.5, 40)	0.00
TM(56, 35)	0.00	TM(52.5, 35)	0.16*	TM(59.5, 35)	0.00
TM(56, 30)	0.01	TM(52.5, 30)	0.00	TM(59.5, 30)	0.00
TM(56, 25)	0.50*	TM(52.5, 25)	0.00	TM(59.5, 25)	0.00
TM(56, 20)	0.65*	TM(52.5, 20)	0.00	TM(59.5, 20)	0.00
TM(56, 15)	0.24*	TM(52.5, 15)	0.00	TM(59.5, 15)	0.01
TM(56, 10)	0.06*	TM(52.5, 10)	0.00	TM(59.5, 10)	0.29*

Notes: Test statistics were constructed using the Newey–West (1987) covariance matrix estimator.

p-values, $\alpha_0 = 0$; $\beta_1 = 1$.

*Test of unbiasedness is satisfied.

The third column of Table 3 reports the results of p-values for test 2. The results suggest that the null hypothesis of $\gamma = 0$ is rejected for 18 asymmetric trimmed means out of 43 unbiased asymmetric trimmed means at 5% significance level. This means that the 18 unbiased asymmetric trimmed means have passed this test and so can be considered to be leading indicators of headline inflation.

Third column of Table 4 presents results of the first part of test 3, namely p-values of the t-test for the $\lambda = 0$ in Equation 8 i.e. weakly exogenous property of core inflation. The test results show that all the 18 asymmetric trimmed means that passed test 2 also pass the weak exogeneity test. However, the results of the second part of Test 3, namely ($\lambda = \theta_1 = \dots = \theta_s = 0$) in Equation 8 presented in the fourth column of Table 4, show that of these 18 asymmetric trimmed means, the null hypothesis of strong exogeneity is satisfied only for five asymmetric trimmed means at 5% level of significance. These five asymmetric trimmed means are TM(55, 20), TM(56, 20), TM(54.5, 25), TM(55.5, 20), and (56.5, 20). It should be noted that in case of TM(54.5, 25), the p-value of Wald test is 0.22 and the p-values for TM(55, 20), TM(56, 20), TM(55.5, 20), and (56.5, 20) are 0.050, 0.054, 0.053, and 0.051, respectively (see fourth column of Table 4).

To check the robustness of the results for strong exogeneity test, the test 3 was also conducted for shorter sample periods for 18 asymmetric trimmed means that passed the weak exogeneity test. In particular, we estimated Equation 8 with various numbers of lagged values of headline and

Table 3. Test 2-attractor property of core inflation

	Test 1: unbiased property of core inflation	Test 2: attractor property of core inflation
Unbiased asymmetric trimmed mean core inflation measures	p -value, $\alpha_0 = 0; \beta_1 = 1$	p -value, $\gamma = 0$
TM(51, 45)	0.16	0.22
TM(52, 40)	0.22	0.19
TM(53, 35)	0.45	0.23
TM(54, 35)	0.20	0.40
TM(54, 30)	0.51	0.17
TM(55, 30)	0.41	0.32
TM(55, 25)	0.54	0.08
TM(55, 20)	0.12	0.02*
TM(56, 25)	0.50	0.17
TM(56, 20)	0.65	0.03*
TM(56, 15)	0.24	0.01*
TM(56, 10)	0.06	0.01*
TM(57, 20)	0.57	0.08
TM(57, 15)	0.83	0.03*
TM(57, 10)	0.42	0.01*
TM(58, 15)	0.65	0.05*
TM(58, 10)	0.97	0.03*
TM(59, 15)	0.09	0.14
TM(59, 10)	0.64	0.05*
TM(60, 10)	0.09	0.15
TM(52.5, 40)	0.19	0.26
TM(52.5, 35)	0.16	0.18
TM(53.5, 35)	0.50	0.30
TM(53.5, 30)	0.20	0.13
TM(54.5, 30)	0.66	0.23
TM(54.5, 25)	0.23	0.05*
TM(55.5, 30)	0.11	0.44
TM(55.5, 25)	0.70	0.11
TM(55.5, 20)	0.34	0.02*
TM(55.5, 15)	0.08	0.01*
TM(50.5, 25)	0.18	0.25
TM(56.5, 20)	0.78	0.05*
TM(56.5, 15)	0.53	0.02*
TM(56.5, 10)	0.18	0.01*
TM(57.5, 20)	0.24	0.13
TM(57.5, 15)	0.90	0.04*
TM(57.5, 10)	0.74	0.02*
TM(58.5, 15)	0.30	0.09
TM(58.5, 10)	0.94	0.04*

*Test of attraction is satisfied.

Table 4. Test 3-exogenous property of core inflation

	Test 2: attractor property of core inflation	Test 3: exogenous property of core inflation (i)	Test 3: exogenous property of core inflation (ii)
		Weak exogeneity p -value, $\lambda = 0$	Strong exogeneity p -value, $\lambda = \theta_1 = \dots = \theta_s = 0$
$TM(55, 20)$	0.018	0.861*	0.050**
$TM(56, 20)$	0.033	0.615*	0.054**
$TM(56, 15)$	0.014	0.698*	0.003
$TM(56, 10)$	0.009	0.594*	0.001
$TM(57, 15)$	0.026	0.502*	0.003
$TM(57, 10)$	0.014	0.406*	0.001
$TM(58, 15)$	0.057	0.327*	0.003
$TM(58, 10)$	0.028	0.244*	0.001
$TM(59, 10)$	0.054	0.135*	0.000
$TM(54.5, 25)$	0.056	0.650*	0.222**
$TM(55.5, 20)$	0.024	0.741*	0.053**
$TM(55.5, 15)$	0.012	0.794*	0.003
$TM(56.5, 20)$	0.050	0.490*	0.051**
$TM(56.5, 15)$	0.019	0.600*	0.003
$TM(56.5, 10)$	0.011	0.500*	0.001
$TM(57.5, 15)$	0.037	0.409*	0.003
$TM(57.5, 10)$	0.020	0.320*	0.001
$TM(58.5, 10)$	0.042	0.181*	0.000

*Test of weak exogenous is satisfied.

**Test of strong exogenous is satisfied.

Table 5. Test 3-exogenous property of core inflation. Estimation sample: 1999:04–2008:04

	Test 3: exogenous property of core inflation	
	Weak Exogeneity, p -value, $\lambda = 0$	Strong Exogeneity, p -value, $\lambda = \theta_1 = \dots = \theta_s = 0$
$TM(55, 20)$	0.76*	0.07**
$TM(56, 20)$	0.67*	0.08**
$TM(54.5, 25)$	0.77*	0.20**
$TM(55.5, 20)$	0.72*	0.08**
$TM(56.5, 20)$	0.63*	0.09**

*Test of weak exogenous is satisfied.

**Test of strong exogenous is satisfied.

asymmetric trimmed means and for different sample periods. The findings confirmed the earlier full sample results that the five asymmetric trimmed means namely: $TM(55, 20)$, $TM(56, 20)$, $TM(54.5, 25)$, $TM(55.5, 20)$, and $TM(56.5, 20)$ are fulfilling strong exogenous property of core inflation. The results are reported in Table 5 for these five trimmed mean series for the sample period 1999:04–2008:04.

Any one of the five asymmetric trimmed means that passed the three properties of core inflation can be used as core inflation measures. For instance, the Figure 4 plots the $TM(54.5, 25)$ and $TM(55, 20)$. As figure demonstrates, these two asymmetric trimmed means overlap each other, and they display very similar movements over the sample period.

Figure 4. Asymmetric trimmed means.

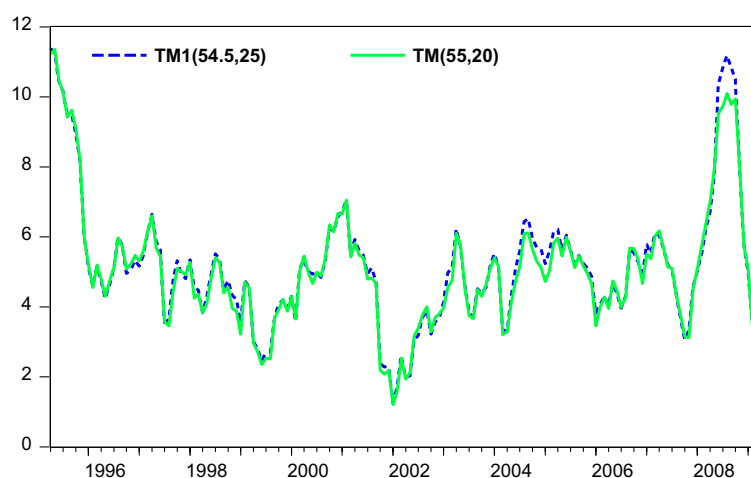


Table 6. Relative variance of core inflation indicators

	WPI	TM(55, 20)	TM(56, 20)	TM(54.5, 25)	TM(55.5, 20)	TM(56.5, 20)
Variance	0.68	0.53	0.56	0.53	0.55	0.58
Relative variance	1.00	0.79	0.83	0.79	0.81	0.85

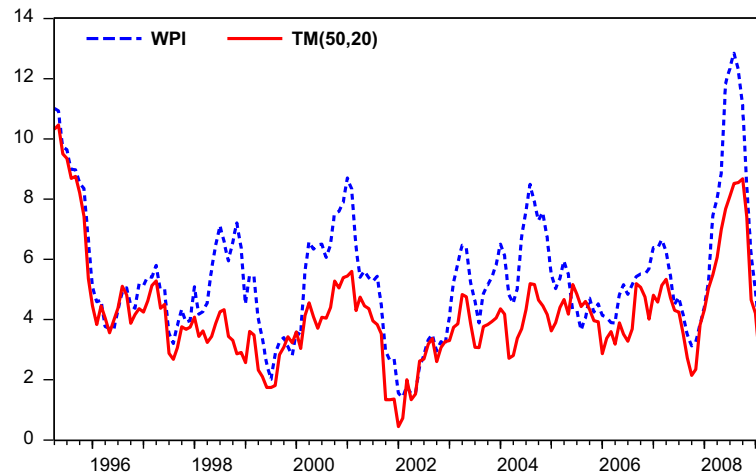
To further select the best among the five core measures, we need an additional criterion. Following again Marques and Mota (2000), we choose a core inflation measure that exhibits smallest variance among five alternative measures of core inflation. This additional criterion shows that the selected core inflation indicator exhibits a small short-term volatility, and therefore would be a good trend indicator of headline inflation. Variance of core inflation measures and headline inflation are reported in Table 6. Variance (short-term volatility) is compared by considering the quotient between the variance of the first difference of each core inflation measure and variance of the first difference of headline inflation. This criterion can also be viewed as relative efficiency of core inflation vis-à-vis headline inflation.

First row of Table 6 shows that the variance of each core measure is lower than the variance of headline inflation. Among the five measures, the variance of $TM(54.5, 25)$ is the smallest, which is therefore considered the optimal core inflation indicator in the class of the trimmed mean measures. The $TM(54.5, 25)$ is the 25% trimmed mean centered on the 54.5th percentile i.e. the percentile interval of [29.5, 79.5]. This is the weighted asymmetric trimmed mean obtained by trimming 29.5% from the left-hand tail and 20.5% from the right-hand tail of the price changes distribution.

4.1. Symmetric versus asymmetric trimmed mean core measures in India

In Indian context, some effort has been made to construct core inflation using symmetric trimmed mean estimators. Among these, Mohanty et al.(2000) were the first to construct trimmed means in India. They calculated three symmetric trimmed means (5, 10, and 15% trim from each tail) over the period April 1983 to March 1999. Following Bryan et al. (1997) recommended RMSE approach as an evaluation criterion, they found 10% symmetric trimmed mean as a good core inflation measure for India. Subsequently, similar results are reflected in Joshi and Rajpathak (2004). Recently, Das, John, and Singh (2009) calculated median and symmetric trimmed mean that trim 8% from each tail of the distribution of price changes. The graphs based on these measures, that show core inflation as well as WPI for period 2000:01–2007:12, clearly establish that core inflation throughout the period lies below WPI, thus indicating that such core inflation measures tends to systematically underestimate WPI inflation. Kar (2009) computed different statistical measures of core inflation and proposed 57th percentile measure as an indicator of core inflation for India.

Figure 5. Symmetric trimmed mean and WPI inflation.



Given that distribution of price changes in India exhibits chronic right skewness, it is imperative to understand how symmetric trimmed means systematically underestimate the WPI inflation rate. Figure 5 plots, for example, 20% symmetric trimmed mean $TM(50, 20)$ and WPI inflation over the sample period. As can be seen, symmetric trimmed mean series $TM(50, 20)$ is most of the time below the WPI inflation rate. The graph uncovers the fact that the symmetric trimmed mean is not a very useful trend inflation indicator of WPI inflation as it fails to estimate true level of core inflation. This is also true for any symmetric trimmed mean of LIE, as Marques and Mota (2000) showed that simply changing the total amount of trimming in a symmetric way can change only the expected value of the estimator. The results in the previous section provide evidence that none of the computed symmetric trimmed means satisfied the unbiased mean test.³

5. Conclusion

This paper used the asymmetric trimmed mean approach to measure core inflation for India. We computed several trimmed mean measures of core inflation and subsequently evaluated them according to conditions specified in Marques et al. (2000), in order to find the best measure in the class of the trimmed means measures. For this purpose, the paper first analyzed the key characteristics of distributions of price changes for India. This provided empirical evidence to justify use of asymmetric trimmed mean estimators as the appropriate estimators of core inflation for India.

Among the several trimmed means, five asymmetric trimmed means satisfied all the three necessary evaluation criteria of core inflation. Therefore, they can be used as core inflation indicators for India. The final suggested core inflation measure was one with the smallest relative variance. This is asymmetric trimmed mean $TM(55.4, 25)$, corresponding to percentile interval [29.5, 79.5], with 29.5% trim from the left-hand tail and 20.5% trim from the right-hand tail of the distribution of price changes.

The paper also provided the method of trimmed mean expression 'in terms of percentile score' to show precisely where the percentile interval used for calculating core inflation is centered and what is the average percentage of trimming from both side of the tails.

Given asymmetric distribution for the price changes in India, the paper also graphically demonstrated that the symmetric trimmed means are systematically downward biased relative to WPI inflation as it was always below the WPI inflation rate over the sample period. This highlights the limitation of symmetric trimmed means and the importance of asymmetric trimmed mean for capturing underlying inflation for India.

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Author details

Naresh Kumar Sharma¹
 E-mail: nareshss@uohyd.ernet.in
 Motilal Bicchai²
 E-mail: bmotilal@gmail.com

¹ School of Economics, University of Hyderabad, P.O. Central University, Prof C. R. Rao Road, Hyderabad 500046, India.

² Department of Economics, Sangameshwar College, Solapur 413005, India.

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Notes

1. Empirical evidence as summarized in Roger (2000), clearly suggests that the distributions of price changes in different countries and time periods are found to be leptokurtic and positively skewed.
2. Measured inflation, headline inflation, and Wholesale Price Index (WPI) inflation are used here as interchangeable terms.
3. This is also true for any trimmed mean that put relatively more weight on right hand tail of the distribution.

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