Measuring Core Inflation in India: An Application of Asymmetric-Trimmed Mean Approach

Motilal Bicchal* Naresh Kumar Sharma **

Abstract

The paper seek to obtain an optimal asymmetric trimmed means-core inflation measure in the class of trimmed means 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 evaluated by the conditions set out in Marques et al. (2000). The data used in the study is the monthly 69 individual price indices which are constituent components of Wholesale Price Index (WPI) and covers the period, April 1994 to April 2009, with 1993-94 as the base year. Results of the study indicate that an optimally trimmed estimator is found when we trim 29.5 per cent from the left-hand tail and 20.5 per cent from the right-hand tail of the distribution of price changes.

Key words: Core inflation, underlying inflation, asymmetric trimmed mean

JEL Classification: C43, E31, E52

* Ph.D Research scholar and ** Professor at Department of Economics, University of Hyderabad, P.O Central University, Hyderabad-500046, India.
Corresponding author: ***bmotilal@gmail.com***

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1. Introduction

Various approaches to measuring core inflation have been discussed in the literature. Among these, the Limited Influence Estimator (LIE) approach has gained considerable attention due to its statistical and economic rationale. Two estimators are classified under the LIE approach: conventional symmetric trimmed mean and asymmetric trimmed mean. Use of symmetric trimmed mean and median as a core inflation measure is justified on the grounds of its efficiency when the distribution of price change is symmetric though leptokurtic. However, when distribution of price change is positively skewed[1], symmetric trimmed mean estimators are biased estimators of measured inflation. For eliminating this systematic bias, Roger (1997) pioneered asymmetric trimmed mean approach. Subsequently, this approach has been applied by researchers in the various countries.

Mohanty *et al* (2000) were the first to construct a LIE based core inflation measure for India. Some other studies have also used LIE method for measuring core inflation for India. However, these studies have computed symmetric trimmed means. As noted above, and as we show later, given skewnees in the distribution of price changes in Indian data, the symmetric trimmed mean estimator will produce a core inflation rate that systematically underestimates the headline inflation rate. Consequently, the symmetric trimmed mean may not be a very useful estimator of underlying trend inflation in India.

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

The paper is organized as follows: Section 2 discusses the literature on limited influence estimator (LIE) as a core inflation measure, highlighting its statistical issues relating to symmetric vs. asymmetric trimming. Section 3 describes key characteristics of cross-

[1] Empirical evidence as summarized in Roger (2000), clearly suggests that the distribution of price changes in different countries and time periods are found to be leptokurtic with positively skewed distribution.

sectional distribution of price changes in India. Section 4 deals with the computation of the various trimmed means for India and an evaluation of these measures according to pre-specified criteria. The section ends with some comparisons between symmetric and asymmetric trimmed mean core inflation estimates for India. The last section offers some concluding observation.

2. Limited Influence Estimator: An Overview

Limited influence estimator (LIE) is an alternative approach for conventional ex-food and ex-energy core inflation measures. The basic idea of LIE approach to deriving core inflation 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 same or all of subsequent periods.

The use of LIE for estimating core inflation rate is generally supported both in 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 is the best estimator of central tendency, in the presence of non-normality in the distribution of price change.

2.1 Symmetric vs. Asymmetric Trims

Consider that there are n commodity groups. Let the proportionate price changes in a given period t for these commodity groups be arranged in an increasing order (from lowest to the highest) as $\pi_{1t}, \pi_{2t,......,} \pi_{nt}$. Let the corresponding weights of these commodity groups in the total commodity basket be $w_1, w_2, ..., w_n$ respectively. We denote cumulative weight of commodity groups 1, 2… i as $W_i \left(= \sum_{k=1}^{i} w_k\right)$. If α% is

[2] Measured inflation, headline inflation and WPI inflation are used here as interchangeable terms.

trimmed from each of the tails of this distribution, the interval $\left[\alpha/100\,,\ 1-\alpha/100\right]$ is called the untrimmed range. A commodity group i is included in the inflation measure, if W_i falls within the untrimmed range. We define $\mathrm{I}_\alpha = \left\{i \mid \alpha/100 \le W_i \le 1-\alpha/100\right\}$. The α% trimmed mean is given as:

$$\pi^*_{t\,\alpha} = \frac{1}{1-2\frac{\alpha}{100}} \sum_{i\in \mathrm{I}_\alpha} w_i \pi_{it}$$

Here α% is trimming from each of left and right tails of the distribution and the 50th percentile is the centre of trimming. The mean and the median of the distribution of price changes are then as special cases of trimmed means namely, with a trimming percentage (α) of 0% and 50 % respectively from each tail.

The starting hypothesis of LIE is that under assumption that price change are distributed normally, sample mean of price change distribution (measured inflation rate) is an unbiased and efficient estimator of the unknown population mean. Further, median, mean and mode will coincide under the normality assumption; therefore each of these central tendencies can represent underlying trend inflation.

If the distribution of price changes is symmetric but exhibits high *kurtosis*, then sample mean is an unbiased but inefficient estimator of sample mean (Roger 2000). Bryan and Cecchetti (1993) found such characteristics of price distribution for the U.S data. They proposed use of median as core inflation measure. Later Bryan *et al* (1997) examined efficiency of inflation estimate for purpose of monetary policy. They argued that since the observed price changes exhibit high levels of kurtosis, so simple averages of price data no longer provide efficient estimates of inflation. Given this observation, they suggested the symmetric trimmed-mean as a core inflation measure. They also show that the more leptokurtic the price distribution, the larger the ideal trim. The basic idea behind Bryan and Cecchetti (1993) Bryan *et al* (1997) proposed median and symmetric mean is that if the kurtosis of empirical distribution of price changes is larger than that of a normal distribution, then it can be shown that "an estimator for the mean that puts more weight on central price changes, is more efficient than the sample mean" (Marques and

Mota 2000). This is what symmetric mean and median do but not sample mean of price change distribution which gives equal importance to each observation.

Bryan et al (1997) also provide a method of determining the optimal trimming percentage. They examine the entire range of trimmed means, with the trim from each tail going from zero to 50 per cent. The trimmed means are then compared with the 36-month centered moving average of actual CPI inflation, which is supposed to represent the trend (or core) inflation and is therefore used as benchmark. The aim is to find the trimming percentage that minimizes the deviation gap between trimmed means and benchmark measure where the deviation gap is measured by RMSE and the trim that minimized the RMSE was chosen as the optimal trimming percentage. The results of the paper shows that 9% trim from each tail is most efficient estimate of inflation in the sense that it reduces RMSE by around one quarter for CPI than the standard Mean of CPI.

Roger (1995, 1997) found that distribution of price changes in New Zealand showed a high degree of *kurtosis and chronically right skewness.* He noted that sample mean is unbiased but relatively inefficient in the case of *leptokurtic* distribution, while all symmetric trimmed means of limited-influence estimators (including median) are relatively efficient, but they are *systematically* biased due to chronic *skewness*. In case of a positively skewed distribution we know that mode < median < mean. In such case, the effect of $\alpha\%$ largest price changes on the measured inflation would be higher than the effect of $\alpha\%$ lowest prices changes, because as noted by Marques and Mota (2000), the observations in the right hand tail of the distribution are further away from the mean compared to those in the left hand tail. So, If we trim the same percentage from both the tails, the resulting trimmed mean series then has tendency to underestimate the measured inflation (sample mean of price distribution) in a systematic way (and therefore also population mean which can be represented by sample mean). For eliminating this bias, Roger (1997) proposed the 57th percentile as a measure of core inflation for New Zealand data. It was robust and unbiased in case of the leptokurtic distribution with positive skewnees for New Zealand data. This can also be interpreted as a case of asymmetric trimming that is 50 per cent trimmed mean centered on the average mean percentile (57th

percentile for New Zealand). More generally, if the distribution of price changes is positively skewed, then in order to get trimmed mean that is not systematically biased relative to measured inflation rate, we should trim $\alpha\%$ centred on the rightward of 50th percentile. For example, for $\alpha\%$ asymmetric trimmed-mean centered on c^{th} percentile (c >50) we may trim $(c+\alpha-50)\%$ from left tail and $(\alpha+50-c)\%$ from the right tail of the distribution[3]. Thus, the asymmetric trimming approach has the combination property of being unbiased in the case of positive skewness with the efficiency property in the case of leptokurtic distributions.

A number of researchers have found cross-section inflation distribution to be skewed. They therefore followed Roger (1997) pioneered asymmetric trimmed mean approach-for instance in case of Australia (Kearns 1998), Ireland (Meyler, 1999), England (Bakhshi and Yate, 1999), Belgium (Aucremanne 2000) and Portugal (Marques and Mota 2000). It should further be noted that Kearns (1998) and Meyler (1999) used Bryan et al methodology as described above to determine simultaneously 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 minimizes the deviation gap measured by RMSE or MAD relative to reference trend series-a moving average of measured inflation. While Aucremanne (2000) computed the trimmed means by choosing centre between 50th and 60th percentiles and as a first step, he selected the optimal trimmed means as the ones for which the null hypothesis of normality was not rejected according to the Bera-Jarque statistic. Among these, he then selected the optimum trimmed mean that minimizes the average absolute error relative to the inflation rate. Marques *et al* (2000), on the other hand, criticized use of benchmark-reference trend series as a device to search optimal trimmed mean series. They argued that trend reference measure such as centre moving

[3] There is a trade-off between efficiency and unbiasedness. Bakhshi and Yate (1999), and Meyler (1999) justify trimming more from the right side of the distribution in order to get minimum variance of resulting trimmed mean series. Marques and Mota (2000) and others stress on the finding trimmed means that is not systematically biased relative to measured inflation rate and subsequently they look trimmed means with minimum relative variance among unbiased trimmed mean series. Roger (1997) examine efficiency of the 57th percentile core measure relative to the sample mean.

average of inflation does not guarantee that it is the best proxy for ‘true trend’ of inflation series on number of accounts[4]. Empirical findings of Luc Aucremanne (2000), Health et al (2004) and Dolmas (2005) etc. also show that the optimal trim varies with smoothness of moving average and also using different proxy reference measures for trend series. Marques *et al* (2000) and Marques and Mota (2000) rather proposed a new set of criteria according to which they do find optimal trimmed mean series. They found positive skewness in the Portuguese price distribution. In such case to find optimal trimmed means, they set two steps, they are described below.

First, they set 50th percentile as a lower limit to computing trimmed means. In case of positively skewed distributions, if computed trimmed is centered on a percentile below 50^{th}, the resulting trimmed means will be systematically biased downwards relative to headline inflation thus resulting in systematic underestimates. Least amount of trimming was decided as 5%. Thus 50th percentile and 5 % trimming set the lower limit for searching unbiased trimmed means. While they set upper limit as average mean percentile (in the Portuguese case it was 56th percentile) and highest level trimming was 50%. Any trimmed mean that is centered on above the average mean percentile, will be systematically biased upwards (overestimate) relative to headline inflation. They searched level of trimming higher than 5 % and lower than 50% i.e. they calculated trimmed mean with trim varying from 5 to 50 per cent in steps of five per cent in the open interval percentile between 50^{th} mean percentile and average mean percentile. They found that asymmetric trimmed means do not statistically exhibit a systematic bias relative to measured inflation rate.

Second, they then evaluated unbiased asymmetric trimmed means by the conditions set out in Marques *et al* (2000) to find best asymmetric trimmed mean among the unbiased asymmetric trimmed means.

The assumption of time-invariant optimal trim, implicit in the above discussion, is open to question and scrutiny. Since trimming parameter depends on the values of the moments of the cross-sectional distribution so even if we found optimal trimmed mean in

[4] See Marques et al (2000) for detailed argument.

one period, it may change in another period with changes in the sample distribution of price changes. Therefore, robustness associated of optimal trimmed mean needs to be established. Moreover, trimming parameters are also sensitive to changes in the degree of disaggregating of price components. One possible solution to former is to check the asymmetric behavior of price distribution over sample period. This can be done by testing the stationarity property of the mean percentile.

3. Cross-Sectional Distribution of Price Changes in 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 in India.

The data used in the study is the monthly 69 individual price indices which are constituent components of Wholesale Price Index (WPI) and covers the period, April 1994 to April 2009, with 1993-94 as the base year. Despite various shortcoming of WPI index, we focus on the WPI mainly because 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 RBI data warehouse website.

The inflation rate of each individual component is the rate of change of that individual 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 rate statistics. 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:

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

where P_{it} is the price index for good *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,

$$\pi_{it} = \left(\frac{P_{it}}{P_{i,t-12}} - 1 \right) * 100$$

Inflation for all commodities, likewise, is defined as:

$$\pi_t = \left(\frac{P_t}{P_{t-12}} - 1 \right) * 100$$

$$= \sum_{i=1}^{n} w_{i0} \frac{(P_{it} - P_{i,t-12})}{P_{i,t-12}} * \frac{P_{i,t-12}}{P_{t-12}} * 100$$

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

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

The higher order, k^{th} weighted central moments of a cross-section distribution are then defined as:

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

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

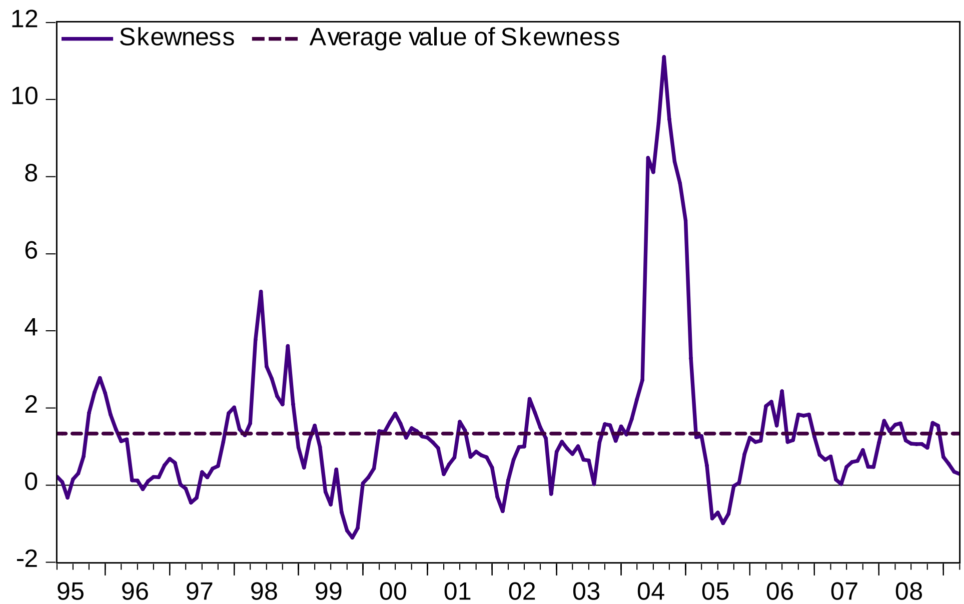
$$S_t = m_{3t} \Big/ \left(m_{2t} \right)^{3/2} \qquad (4)$$

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

The coefficient of skewness (S_t) for a distribution is a measure of asymmetry of the distribution of the series around its mean. The positive skewness coefficient implies that the distribution is skewed to the right and vice-versa. The coefficient of kurtosis (K_t) measure "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), which demonstrate that over the entire 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 and it is equal to 1.34. This finding of positive skewnees is consistent with empirical evidences for other countries - for instant, skewness was found to be 0.70 for New Zealand by Kearns (1998), for Portugal it was 0.83 (Marques and Mota, 2000), for Indonesia 2.24 (Kacaribu, 2002), and for Ukraine 1.23 (Mykhaylychenko and Wozniak, 2004), etc.

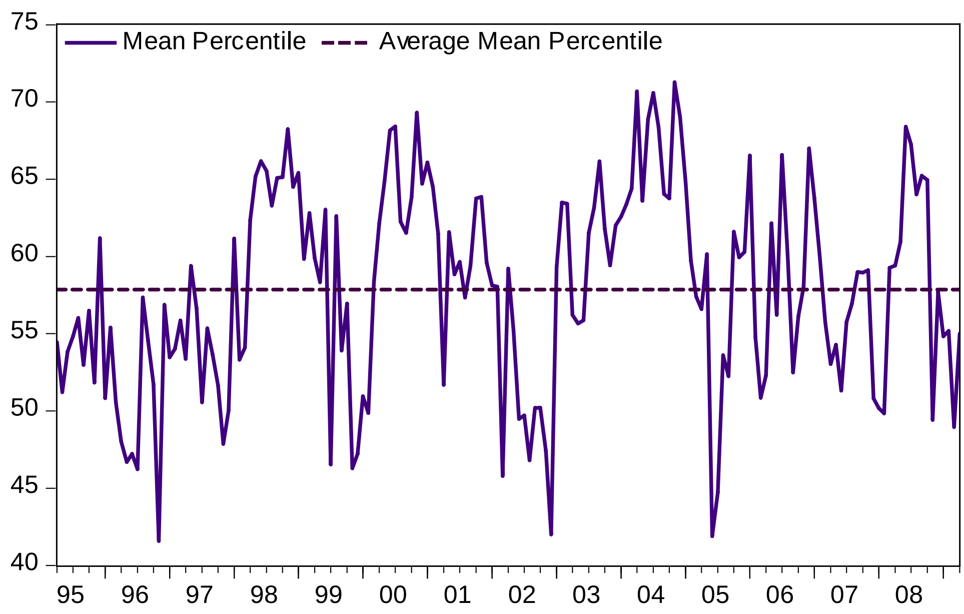
Figure 1



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. As previously noted, the normal distribution indicates mode=median ($\equiv 50^{th}$ percentile)

=mean and the positively skewed distribution indicates mode < median < mean. Therefore, if the distribution of price changes is positively skewed then on average, mean percentile will lie above 50th percentile (i.e., the value of mean percentile will be greater than 50). Accordingly, sample mean of price distribution is also expected to lie above 50th percentile. Figure 2 plots empirical mean percentile for the price change distribution over the sample period. The result suggests that the mean percentiles lie above 50th mean percentile in 153 times out of the 169 month distributions. This finding provides further empirical evidence for the strong chronic positive skewness in the distribution of price changes. The dotted line in the 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 57.85 as shown by doted line in the figure. This indicates that the sample means of price change distribution, on average are contained at 58th percentile.

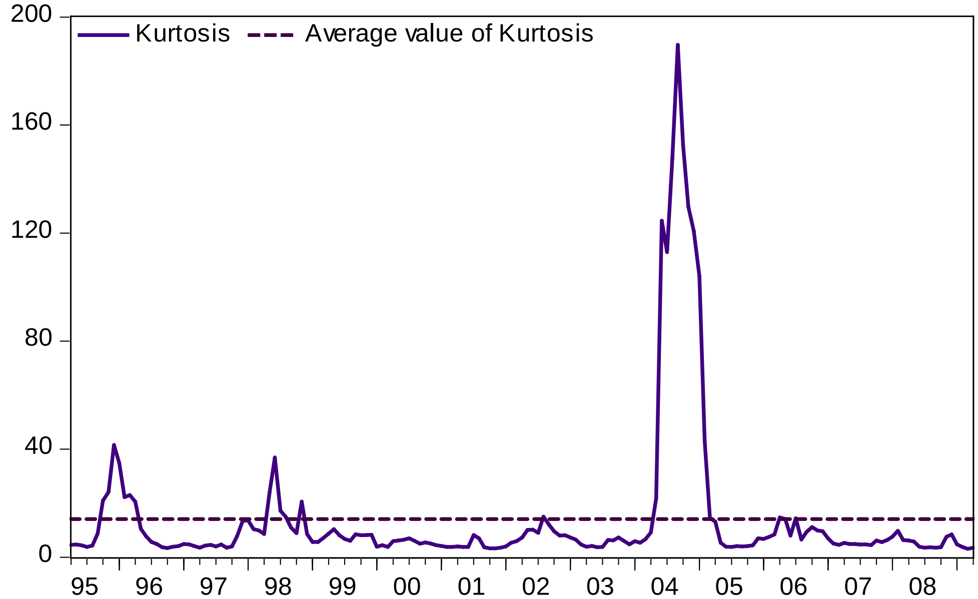
Figure 2



Finally, Figure 3 plots kurtosis of coefficient (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. This result can be clearly seen in the figure.

Figure 3



Overall, the price change distribution in India exhibits leptokurtic and a persistently chronic right skewness. This distinctive characteristic of WPI data is consistence with the findings for other countries data and time periods. The result would therefore suggest for application of asymmetric trimmed mean approach to Indian data for deriving core inflation measures.

4. Trimmed Mean Measures for India

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

4.1 Asymmetric Trimmed Mean Inflation Estimators

Before going on to compute trimmed means, it is important to address the issue of time series behavior of asymmetry (skewness) of price change distribution. This can be checked by testing for the stationarity of the mean percentile. The second row of table 1 presents results of unit root test for mean percentile. The unit root tests 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 and Mota, 2000). Consequently, the degree of asymmetry can be assumed as constant. Further, if we compute trimmed mean under the assumption of constant asymmetry, when in fact it is time varying then the computed trimmed mean core inflation will not be co-integrated (if inflation, is I(1)) with headline inflation or statistically will not have the same mean (if inflation, is I(0)) as the headline inflation.

Trimmed means are computed by choosing various values of left trim and right trim based on 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 centre (c) and a trim (α) as fallows: 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 centre $c = \frac{l+r}{2}$ and trim $\alpha = 50 - \left(\frac{r-l}{2}\right)$, and we represent it as $TM\left(\frac{l+r}{2}, 50\frac{r-l}{2}\right)$. 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 per cent trimmed mean centred on the 55th percentile, is short for percentile interval of [10, 90], which is nothing but trimming symmetrically 10 per cent of to the smallest and 10% of the largest price changes or 10 per cent from each tail of the price change distribution. A TM (57, 15) denotes 15 per cent trimmed mean centred on the 57th percentile, gives percentile interval of [22, 92], which is obtained by asymmetrically trimming the smallest 22 per cent and the largest 8 per cent price change. Likewise a TM (45, 20) represents interval [15, 75], but, since distributions of price changes are positively skewed on average, we ignore the case like the last example. This method of representation has the advantage of explicitly showing where the percentile interval (used for calculating core inflation) is centred and what the average trimming from the two tails is.

Trims (α's) are at interval of 5 percentile points from 10 percentile to 45 percentile and we choose all centers (c's) between 50th percentile and 60th percentile at the interval of 0.5 percentile points. Thus, a total 168 trimmed means are computed over the sample period 1995m04 to 2009m04. Note the symmetric trimmed means are a special case in this procedure, when we chose $c = 50$.

4.2 The Optimal Asymmetric Trimmed Means: Evaluation Criteria and Results

This subsection evaluates different trimmed means in order to find optimal asymmetric trimmed means as core inflation measures. For this purpose, 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 measuress. The three tests and the results based on these test are discussed below:

Test 1: Unbiased 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 are cointegrated 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 can not be co-integrated with core inflation. In such case, it is sufficient that $E\ (\pi_t - \pi_t^*) = 0$ should satisfy i.e. headline and core inflation series should have equal unconditional mean. We test this condition by restriction $a_0 = 0; \beta_1 = 1$ in the static regression:

$$\pi_t = a_0 + \beta_1 \pi_t^* + u_t \tag{6}$$

Core inflation measures that pass this test are unbiased estimators. The OLS estimation of regression (6) exhibits strong auto correlation therefore the standard error for regressions are computed using Newey-West (1987) procedure with 4 lag. Table 2 reports the results of *p*-values from F-statistics for 168 trimmed means. The results indicate that among 168 trimmed means, 43 pass this test. All these 43 trimmed means are asymmetric trimmed means.

Test 2: Attractor Property of Core Inflation:

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

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

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 describe the long-term causality relationship from core to headline. The condition is thus to test attractor property of core inflation by simply testing the null hypothesis of 'no attraction', $\gamma = 0$, using t- test statistic. The practical question in the estimation of equation (7) would be selecting the number of lags for m and n. We set the number of lags based on Schwarz Information Criterion (SIC).

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 per cent significance level. This means that the 18 unbiased asymmetric trimmed means have passed this test and so can be as leading indicators of headline inflation

Test 3: Exogenous Property of Core Inflation:

π_t^* has to be strongly exogenous for the parameters in the equation (7). This implies that in the error correction model for π_t^*:

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

and the hypothesis $\lambda = \theta_1 = ... = \theta_s = 0$ 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 ($\lambda = \theta_1 = ... = \theta_s = 0$) in the above equation. We again here use Schwarz Information Criterion (SIC) to set the number of lags.

Third column of table 4 presents results of the first part of test: 3, namely *p*-values of the t-test for the λ=0 in equation (8) i.e. weakly exogenous property of core inflation. The test results show that all of 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 that ($\lambda = \theta_1 = ... = \theta_s = 0$) in equation (8) in the fourth column of table 4 shows that among the 18 asymmetric trimmed means (that passed the weak exogeneity test (λ =0)), the null hypothesis of strong exogeneity is satisfied only for 5 asymmetric trimmed means at 5 per cent level of significance. These 5 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 noticed 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 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), 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 1999m04 to 2008m04.

All of the five asymmetric trimmed means that passed the three properties of core inflation can be used as core inflation measures. Each of these 5 core inflation measures are statistically equal. For instance, the Figure 4 plots the TM (55, 20) and TM (54.5, 25). As figure demonstrates, these two asymmetric trimmed means overlap each other, they display vary similar movements over the sample period. Nevertheless, to further select among 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 makes it 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 measured by 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 the table 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 the optimal core inflation indicator in the class of the trimmed mean measures. The TM (54.5, 25) is the 25 per cent 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 per cent from the left-hand tail and 20.5 per cent from the right-hand tail of the price changes distribution.

4.3 Symmetric vs. Asymmetric Trimmed Mean Core Measures in India

As has been discussed previously, when the distribution is positively skewed, the mean is greater than the median and, therefore all symmetric trimmed means including median underestimate the measured inflation rate in a systematic way.

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 per cent symmetric trimmed mean as a good core inflation measure for India. Subsequently, similar results are reflected in Joshi and Rajpathak (2004). Recently, Das *et al* (2009) calculated median and symmetric trimmed mean that trim 8 per cent from each tail of the price change distribution. The graphs based on these measures, that show core inflation as well as WPI for period 2000:01 to 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.

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 per cent 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 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 sub- section provide evidence that none of the computed symmetric trimmed means satisfied the unbiased mean test[5].

5. Conclusion

This paper applied the asymmetric trimmed mean approach to measuring core inflation in India. It computed several trimmed mean mesures of core inflation and subsequently evaluated them according to conditions specified in Marques *et al.* (2000), in order to find the best measure in a class of the trimmed means measures. For this purpose, the paper first analyzed the key characteristics of price change distributions in India. This provided empirical evidence to justify use of asymmetric trimmed mean estimators as the appropriate estimators of core inflation in 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 per cent trim from the left-hand tail and 20.5 per cent 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 centred and what the average percentage of trimming from both side of the tails.

Given asymmetric price change distribution in India, the paper also graphically demonstrated that the symmetric trimmed mean was 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.

[5] This is also true for any trimmed mean that put relatively more weight on right hand tail distribution.

Figure 4: Asymmetric Trimmed Means

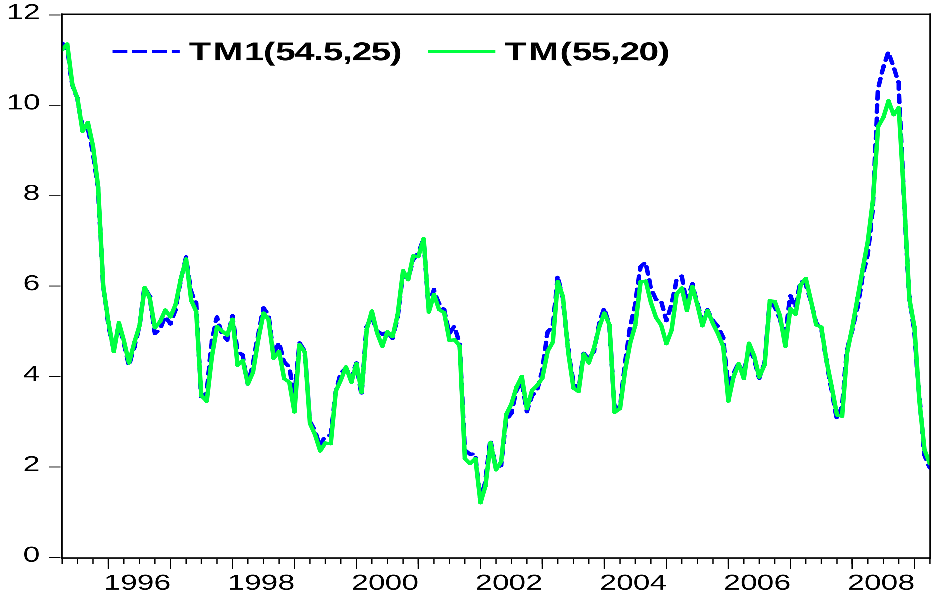


Figure 5: Symmetric Trimmed Mean and WPI Inflation

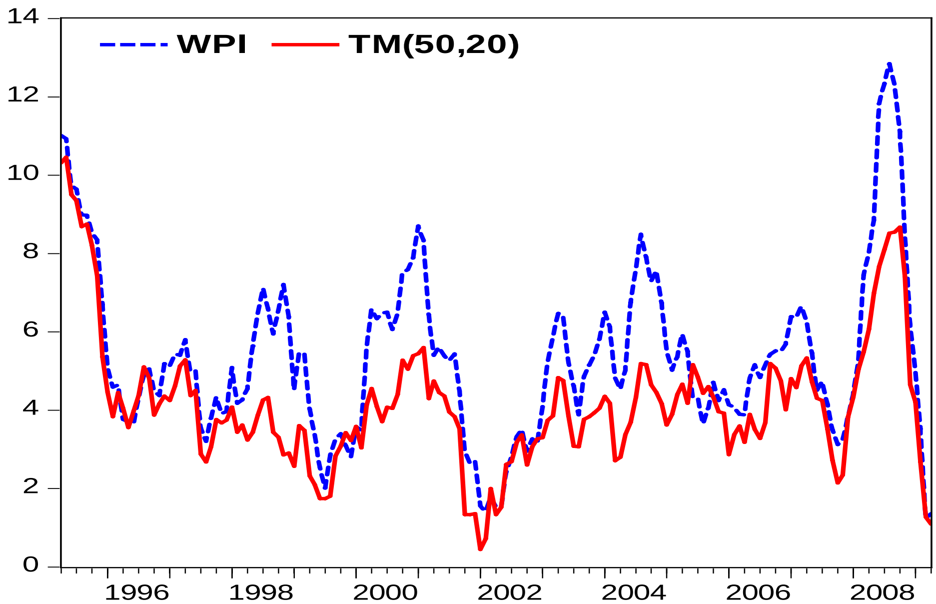


Figure 6: Asymmetric Trimmed Mean and WPI Inflation

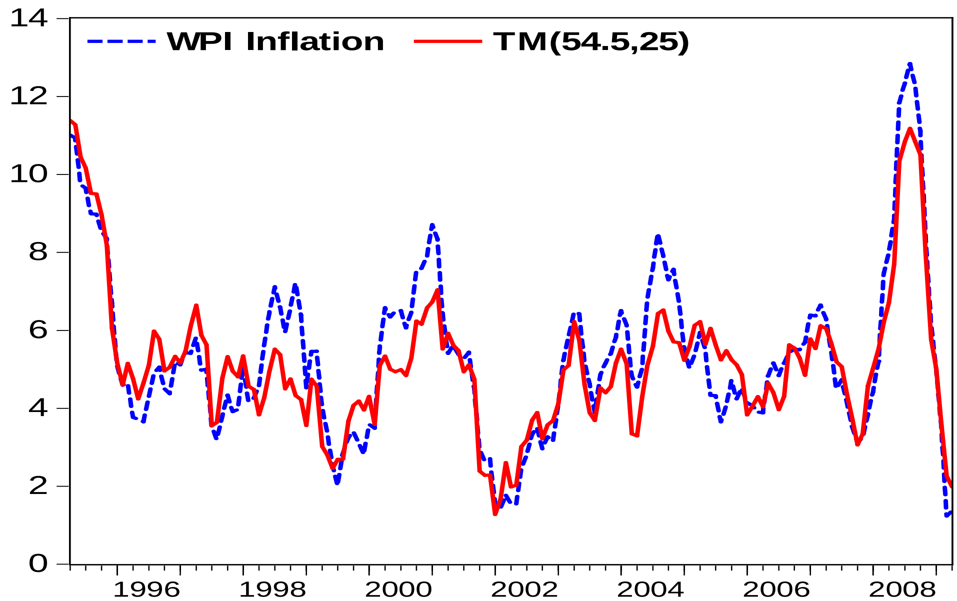


Table 1: Unit Root Tests for WPI Inflation and Mean Percentile

	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: Figure 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 can not 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 can not be rejected

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 (50.5,25)	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*
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 - $a_0 = 0;\ \beta_1 = 1$

* indicate test of unbiasedness is satisfied

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 Means -Core Inflation Measures	*p*-value, $a_0 = 0; \beta_1 = 1$	*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

* indicate 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, λ =0	Strong Exogeneity *p*-value, $\lambda = \theta_1 = ... = \theta_s = 0$
TM (55,20)	0.018	*0.861	**.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

* indicate test of weak exogenous is satisfied
** indicate test of strong exogenous is satisfied

Table 5: Test 3 - Exogenous Property of Core Inflation
Estimation Sample: 1999m04 2008m04

Test 3: Exogenous Property of Core Inflation		
	Weak Exogeneity *p*-value, λ =0	Strong Exogeneity *p*-value, $\lambda = \theta_1 = ... = \theta_s = 0$
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**

* indicate test of weak exogenous is satisfied
** indicate test of strong exogenous is satisfied

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

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