

CORE INFLATION AND MONETARY POLICY IN INDIA

*A Thesis Submitted to the University of Hyderabad for the award of the
degree of*

**DOCTOR OF PHILOSOPHY
IN
ECONOMICS
BY**

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Dedicated to My Parents...

DECLARATION

I **Bicchal Motilal Anand** hereby declare that this thesis entitled “**Core Inflation and Monetary Policy in India**” submitted by me under the guidance and supervision of **Professor Naresh Kumar Sharma and Professor Bandi Kamaiah** is a bonafide research work. I also declare that it has not been submitted previously in part or in full to this University or any other University or Institution for the award of any degree or diploma.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Choice of an appropriate measure of inflation is critically important for the central bank of a country to achieve price stability. However, the general measure of headline inflation, which is measured by the standard aggregate price index, can be volatile, often, because of short term idiosyncratic fluctuations in some component prices. Such volatility in headline inflation would make it difficult for monetary authority to accurately assess the underlying trend and outlook for inflation. Therefore, it is essential to identify signal from noise in headline inflation. In order to do this, economists have developed alternative conceptual measure of inflation, known as “Core Inflation”.

Research on core inflation has been stimulated with the introduction of inflation targeting framework (IT) of monetary policy. A number of central bankers have established explicit inflation target as the central objective of monetary policy. One important operational issue for inflation targeting concerns the following: what price index to use as a target variable? There is some agreement that central banks should be concentrating on stabilizing headline inflation but at the same time it is pointed that headline inflation is heavily affected by non-monetary – supply shock factors – a such as oil price, food and administered prices which are beyond control of monetary authority. As a result, many studies have tried to identify more accurate underlying trend in inflation. A number of core inflation measures have been proposed. They deal systematically with what part is volatile and what part is persistent in measured inflation.

The problem is that despite much research on core inflation, there is no agreement on a single operational definition or method of measuring core inflation because the core inflation itself is unobservable and has to be estimated. Further, there is no single way to identify what constitutes “underlying trend for inflation”. Given these characteristics of

core inflation, there are several approaches to measuring core inflation. This complicates the task. Thus in this study, an attempt has been made to understand primarily the conceptual framework and measurement aspects of core inflation and subsequently to estimate different core inflation measures.

As noted above, one important operational use of core inflation is as a direct target variable in IT framework. Second, and irrespective of type of policy framework adopted in practice, core inflation can be vary useful for assessing underlying trend inflation and outlook for inflation for effective monetary policy. Various core measures that have been proposed in the literature are loosely based on a macroeconomic theory of the cost of inflation. It is well known that monetary policy would operate more effectively on aggregate demand (AD) side of economy, its action effectively manages inflation development originating from AD side and may not be effective in controlling inflation movement when it is generated from aggregate supply (AS) side factors. Core inflation by definition represents AD pressure in the economy. Hence, monetary policy can work effectively on this part of inflation. Since, the headline inflation is prone to supply shocks and given monetary transmission lag, it is important to realize that the monetary policy need not respond to changes in relative prices on account of supply shocks. A policy response at time ' t ' to temporary supply shock to inflation may hit growth without reducing shock inflation and it affects inflation only at time ' $t+h$ ' ($h>0$), gradually when inflation in fact might have reversed to its trend level. The final outcome of such policy would then be increased volatility in inflation and output, which is the opposite of what monetary policies are supposed to achieve/seek: prices stability and sustainable output growth. Therefore, it has been often argued that for effective monetary policy, the central banks should use or monitor core inflation for its best assessment of current underlying trend and future inflation in the process of monetary policy formulation. In the present study an attempt has been made to evaluate various empirical measures of core inflation in this framework.

1.2 Scope and Motivation of the Study

In India RBI has no explicit inflation targeting. It indeed has multiple objectives viz., price stability, growth and stable exchange rate. In April-1998, the RBI formally

announced shifting of its policy framework from monetary targeting to multiple indicator approach (see, Mohanty, 2010). Under this approach, the RBI considers various economic and financial variables to draw monetary policy perspective. Nevertheless, The RBI publishes its inflation forecast which is revised in every quarter and emphasis is placed on anchoring inflation expectation and is committed to maintain its forecasted inflation in specific band. RBI also analyses the sectoral inflation development such as food, fuel group, and other group of commodity and its impact on overall inflation development. Therefore, there is role for different core measures in assessment of future inflation path and its day-to-day analysis of price development for effective operation of monetary policy. Further, the recent demand shock to oil prices and persistency in commodity prices particularly in an emerging economy like India has induced the use of core inflation in policy making.

So far there is no serious attempt to develop core inflation measures for India. Therefore, there is need to develop core inflation measures. This study contributes to the existing literature in india in several ways; first, it computes a number of core measures, some of which are computed for first time in Indian case; secondly, this study provides evaluation and comparison of those core measures in a systematic testing framework in order to suggest some useful core measures for purpose of monetary policy in india; and lastly, it examines operational use and role of core inflation in Indian monetary policy using SVAR approach, which is itself a new approach to analyze usefulness of core inflation in VAR model of monetary policy. Accordingly, the objectives are outlined as follows.

1.3 Objectives of the Study

In the light of this background, the objectives of the present study are set as follows:

- 1) To find out the best trimmed means-core inflation measure in the class of trimmed means measures for India when distribution of price change is leptokurtic and skewed to the right.
- 2) To estimate alternative measures of core inflation for India
- 3) To evaluate performance of alternative core measures in a systematic testing framework in order to suggest some useful core measures for India

- 4) To identify monetary policy shocks by modelling policy reaction function of the RBI and structure of the economy in VAR's model.
- 5) To analyze operational use and relative role of core inflation measures in monetary policy formulation using VAR framework.

1.4 Methodology and Data Base of the Study

The study constructs several statistical based core measures for India and provides a detail methodology on the construction of those core measures. The starting point of these core measures is that they use information either in terms of the aggregate time-series of price index or disaggregate time series of price indices or exploiting the information of the cross-section of individual price changes of prices indices in each period. These statistical methods of core inflation are as follows:

(1) Exclusion Principle: A) Permanent exclusion: subjective approach and B) Permanent exclusion: objective approach. (2) Limited Influence Estimator (LIE) Approach: A) Asymmetric trimmed mean core measures, B) Median and Percentile core measures and C) Month by month exclusion (dynamic trimmed mean measures). (3) Re-weighting approach: A) Variations of neo-Edgeworthian core inflation measures and B) Persistence-weighted measures of core inflation. (4) Univariate-trend Approach: A) Weighted exponential smoothing core measures and B) HP filter measures.

For computing these various core measures, the study uses a detailed breakdown of the WPI based on price indices for 69 separate items and covers the period, April 1994 to April 2009, with 1993-94 as the base year. Trend based measures are derived using aggregate WPI inflation series for the same period. Different statistical methods are employed in the computation process. For instance, the Laspeyres type index, variations of Neo-edgeworthian index, AR (p) model, standard deviation of individual component either over the time or on a cross-section basis etc. are used. For computing some measures, 69 price indices of WPI are seasonally adjusted with X12-ARIMA procedures. Discussion and detailed methodology for computing each of these measures is given in each of core measure section separately in the thesis.

Just as there is no single universally accepted measure of core inflation, likewise there is no agreed empirical criterion for selecting best core measure among alternative core

measures. With that in mind, alternative measures of core inflation are evaluated in a systematic empirical framework. These empirical criteria of core inflation are:

(1) Unbiasedness, Attraction and Exogeneity (UAE):

Core inflation series should be unbiased with respect to the headline inflation

Core inflation should be an 'attractor' of the headline inflation.

Core inflation should be (strongly) exogenous with respect to the headline inflation

(2) Tracking Trend Inflation

Stability and relative volatility of core measures

An ability to track the trend in headline inflation

(3) An Ability to Predict Future Transient Movement in Headline Inflation

(In sample and out of sample forecast evaluation)

Marques, Neves and Sarmiento (2000) have proposed a set of three econometric (UAE) tests to evaluate core inflation measures. For this purpose, the unit root tests are first utilized to determine stochastic properties of inflation measures. Subsequently, static regression OLS with robust standard error and F-test statistic are used for testing unbiasedness condition. Second and third condition viz., attractor and exogenous conditions are tested by employing error correction models (ECMs) as in Marques, Neves and Sarmiento (2000). The number of lags in ECMs is selected using Schwarz Information Criterion (SIC).

The stability and relative volatility criterion of core measures are examined with reference to WPI inflation using standard deviation, coefficient of variation and standard deviation of the first difference method. The tracking trend inflation criterion is to examine to what extent different core inflation indicators are useful in providing information about current underlying trend inflation. This criterion has been used in the studies of Bryan, Cecchetti and Wiggins (1997) and Clark (2001) etc. The ability of alternative core measures in tracking long term trend inflation in WPI inflation is measured by mean absolute deviation (MAD)/ root mean squared errors (RMSE) techniques. Two reference long term trend inflation of WPI namely, 37-months central moving average of WPI inflation (CMA37) and HP (14000) filter series of WPI are chosen in the trend evaluation process. The UAE tests are used to choose the best reference trend series among various months CMA of

WPI. To draw some formal statistical inference on the observed differences in RMSE, Diebold-Mariano (1995) test statistics are constructed. The DM test statistic is to test the null hypotheses that two core inflation measures track the trend rate of inflation equally well against the alternative hypothesis that one core inflation measure tracks trend inflation more accurately than the other.

To assess the predictive ability of core measures, ‘gap test’ model are used. The ‘gap test’ model is defined as the change in headline inflation (WPI) from today to some point in the future on the current ‘gap’ between core and headline inflation. This model has often been used in the literature, in studies by Clark (2001), Hogan *et al* (2001), Cutler (2001) and Cogley (2002) etc. This model captures to what extent transient movements will reverse toward core inflation after shock to headline inflation. This model is estimated for both in sample and out of sample analysis over three forecast horizons viz., 12, 18 and 24 months with OLS method. The Newey-West corrected standard errors are used to form the test statistics to account for autocorrelation and possible conditional heteroskedasticity of the regression residuals, which arise due to overlapping observations caused by the forecast horizons. To evaluate the out-of-sample forecasting accuracy, RMSEs of the forecasts are utilized. Further, the rank of RMSEs forecast is used. The rank is computed as an average of the RMSE of all the three forecast horizons for each core measure. As before, the DM tests statistics are computed to examine if the observed differences in RMSEs of forecasts are statistically significant at each forecast horizon. For DM test, core inflation measure associated with the lowest RMSE are selected as benchmark core measure at each forecast horizon and all the other core inflation series are then compared against the benchmark core inflation series on an individual basis.

Towards fourth and fifth objectives, both standard VAR with Cholesky decomposition and Structural VAR model have been employed. Both Impulse Response Function (IRF) and the Forecast Error Variance Decompositions (FEVD) are used for analysis. All VAR models are estimated with constant and with *endogenous and exogenous variables* over the period between April-1998 to April-2009. Variables are transformed in natural logs and also seasonally adjusted using ARIMA X12 procedures, with the exception of the call rate. The endogenous variables included in the VAR models are industrial production index (y), wholesale price index or core price index (p), nominal exchange rate vis-à-vis

the US dollars or nominal effective exchange rate (e), call money rate (r), and broad money aggregate (M). Short term call money rate is used to capture the monetary policy stance. Federal Fund Rate and World Commodity Prices are included in the VAR models as exogenous variables in order to include the world constraint and to capture world inflation in the VAR models. To examine operational use and relative role of core inflation measures in monetary policy formulation, VAR models are estimated for two alternative inflation measures, core measures and WPI measure. Monetary policy shocks are identified in recursive structure of VAR for WPI-ex food and fuel measure (or core prices) and WPI measure. This recursive-VAR approach assumes that RBI modulates the call money rate after observing the current values of prices, output and nominal exchange rate. This assumption is consistent with the multiple indicator approach currently followed by the RBI. These two models are labeled benchmark VAR models. The effectiveness and robustness of the results from benchmark recursive identification model are examined using other alternative ordering and non-recursive identification VAR model, which are in the spirit of Kim and Roubini (2000), and Bredin and Reilly (2004). Then core inflation (price level) targeting scenario using SVAR approach is generated.

1.5 Scheme of the Study

The present study is organized into six chapters. The first chapter deals with introduction, scope, motivation and objectives of the study and briefly spells out the methodology. Chapter 2 reviews various definitions of core inflation and various existing alternative theoretical approaches to measuring core inflation, evaluating their potential advantages and disadvantages and highlighting the theoretical and empirical issues arising in measurement of core inflation. Subsequently, it provides a review of various desirable properties and empirical criteria of core inflation, which have been proposed in the literature for assessing usefulness of core inflation measure among alternatives. Chapter 3 is aimed at finding optimal trimmed mean in case of India using asymmetric trimmed mean as an estimator of core inflation. It computes several trimmed mean measures of core inflation and subsequently evaluates them according to pre-specified criteria, in order to find the best measure in a class of the trimmed means measures. For this purpose, this chapter first analyzes the key characteristics of weighted cross sectional distributions of

price change in India. At the end, it also provides some comparisons between symmetric and asymmetric trimmed mean core inflation estimates for India. Chapter 4 provides details on constructing and implementation of different statistical core measures in India and subsequently evaluates their empirical performance using various empirical criteria of core inflation in a systematic testing framework so as to suggest some useful core measures for India. Chapter 5 provides a VAR analysis of monetary policy in India with two alternative inflation measures viz., WPI and core measures over a period that covers the term after the RBI adopted a multiple indicator approach. The final chapter concludes the thesis with summary of study and the policy implication of the study.

CHAPTER 2

MEASUREMENT OF CORE INFLATION: A REVIEW OF MAJOR APPROACHES AND EMPIRICAL CRITERIA

“for the purposes of monetary policy, what is needed is not a microeconomic theory of the cost of living, but a macroeconomic theory of the cost of inflation. Thus we can interpret various measures of core inflation as attempts to better measure this more-appropriate measure of inflation for monetary policy purposes.”

--- Mark A. Wynne

Federal Reserve Bank of St. Louis Review, May/June 2008,

2.1 Introduction

Economists have developed alternative conceptual measure of inflation, called ‘Core Inflation’. But despite much research on core inflation, there is no agreement on a single operational definition of core inflation. This is because there is no single way to identifying what constitutes “underlying trend for inflation” Given these characteristics of core inflation, there are several approaches to measuring core inflation. An attempt is made to review various definitions of core inflation and various existing alternative theoretical approaches to measuring core inflation, evaluating their potential advantages and disadvantages and highlighting the theoretical and empirical issues arising in measurement of core inflation. For this purpose, the existing literature is divided into two broad categories viz., statistical approaches and modeling approaches. Much of the existing literature argues in favour of adopting statistical approaches in terms of their relative simplicity and statistical foundation. As a result such measures are most frequently used by central banks when compared to model based measures. We therefore focus at some length on reviewing statistical measures of core inflation, specifically Limited Influence Estimator (LIE) of core inflation-discussing its statistical properties and the theoretical model to measuring core inflation.

Given lack of uniformity on how best core inflation could be empirically derived, different statistical criteria have been applied in order to judge the best measures among alternatives. We therefore follow the following framework: uses or goals of core inflation are first described conceptually, and subsequently various empirical properties of core inflation measures are reviewed based on each goals or objectives.

The structure of chapter is as follows. Section 2 discusses various definitions of core inflation. Section 3 provides a review of various alternative approaches and methods to measuring core inflation. Section 4 presents empirical criteria for evaluation of core inflation measures and section 5 concludes the chapter.

2.2 Definitions of Core Inflation

The term core inflation is widely used by academicians, central bankers and researchers. Despite its prevalence, like some other economic concepts, there is no agreed definition of it. Initially and also till now a number of central banks have been publishing the headline inflation after excluding food and energy items. This has been often called “core inflation”. The rationale is that food and energy concern the most volatile, supply shock driven aspects which are deemed to be beyond control of a central bank. Subsequently other definitions that try to identify more accurate trend inflation have been proposed. They deal more systematically with what part is volatile and what part is persistent in measured inflation.

Here we briefly describe some, well-known definitions cited in literature.

Otto Eckstein (1981), is considered the originator of the term “Core Inflation” Eckstein defined it as “the trend increase of the cost of factors of production” and observed that this notion of core inflation “...originates in the long-term expectation of inflation in minds of households and business, in the contractual arrangements which sustain the wage-price momentum, and in the tax system.” (quoted in Roger, 1997, p.2) Eckstein definition divides core inflation into demand, supply shock and production cost.

Quah and Vahey (1995) definition is based on the assumption of a long run vertical Philips curve. They define core inflation “.....as that component of measured inflation that has no medium to long run impact on real output” (p.1130). This definition relates to that

part of inflation which is anticipated, and, is, therefore output neutral in the long run. This notion is consistent with long run Philips curve hypothesis where all volume of inflation pressure is anticipated that leads no trade-off between inflation and output.

To formalize the above two notions of core inflation, and following Roger (1998) let us write:

$$\Pi_t = \Pi_t^{LR} + g(X_{t-1}) + v_t$$

Where:

Π_t is the aggregate inflation rate in period t

Π_t^{LR} is the long-run or trend inflation rate

X_{t-1} is a measure of cyclical excess demand pressure

g captures effect of X on inflation

v_t is a measure of transient disturbances to inflation

Then, Eckstein core inflation is:

$$\Pi_t^C = [\Pi_t - g(X_{t-1}) - v_t] = \Pi_t^{LR} = \text{the long run or trend inflation.}$$

While non-core inflation is, Π_t^{NC} given by:

$$\Pi_t^{NC} = g(X_{t-1}) + v_t$$

Under this definition, core inflation excludes effect of cyclical demand pressure.

Quah and Vahey definition of core inflation is given by:

$$\Pi_t^C = [\Pi_t - v_t] = \Pi_t^{LR} + g(X_{t-1})$$

And non core inflation is:

$$\Pi_t^{NC} = v_t$$

The two definitions are different in sense of inclusion or exclusion of cyclical influences on core inflation. Further, we can look at these differences in terms of Philips curve.

In Eckstein definition, core inflation is related to trend inflation so, it is consistent with long run vertical Philips curve that is associated with anticipated inflation, the cyclical excess demand pressures are component of unanticipated inflation, therefore, it might be consistent with short run Philips curve.

In Quah and Vahey definition, core inflation is constituted by introducing cyclical excess demand pressure also that is seen as a component of anticipated inflation. If unanticipated inflation is considered a short run phenomenon, then one part of Quah and Vahey definition lead to short run Philips curve where cyclical part of core inflation and output will have a trade-off and other part of long run trend inflation is related to vertical Philips curve. Thus, this interpretation of Quah-Vahey definition in terms of above equation can be seen together with Quah-Vahey definition of core inflation as "...a notion consistent with the vertical long-run Philips curve interpretation of the co-movements in inflation". Roger (1998) suggests that we should not overdo the differences: the difference between a transient influence on inflation (v_t) and cyclical ($g(X_{t-1})$) and long-term influences (Π_t^{LR}) is an artificial construct. This distinction should really be drawn with reference to the policymaker's horizon.

Bryan and Cecchetti (1993) explained core inflation by linking it to money growth "In general, when people use the term they seem to have in mind the long-run or persistent component of the measured price index, which is tied in some way to money growth" (pp:3). Indeed, Bryan and Cecchetti formalized the concept of core inflation by decomposing an individual items price change (π_{it}) into two components: a price change common to all items (core inflation (Π_t^C) - which is parallel to the money growth rate) and relative price change resulting from idiosyncratic shocks to individual items (u_{it}):

$$\pi_{it} = \Pi_t^C + u_{it} .$$

Blinder (1997, p.9) has defined the core inflation as "the durable part or persistent component of aggregate inflation." And that "...the durable part of the information in each monthly inflation report was the part that was useful in medium and near-term inflation forecasting".

In spite of such diversity in definition of core inflation, Roger (1998) has explained two broad views of core inflation: one, core inflation as persistent component of measured inflation and two, core inflation as the generalized component of measured inflation. The latter view implies that it is trying to capture a general trend which is present in all commodities while the former view aims at capturing directly the persistent component of inflation. In both the conceptions however, core inflation is generally associated with expectation and demand pressure component of measured inflation.

Headline Inflation and Core Inflation Distinguished:

For more clarity, to distinguish core inflation from headline inflation, the latter is quantified by rate of change of aggregate price index which is essentially a measure of changes in the cost of living of people while the former excludes temporary supply shock components and measures only demand pressure or permanent components of the same index. A headline inflation index constitutes both anticipated and unanticipated part of inflation expectation but core inflation index is related only to anticipated component of the index. Thus core inflation is a proxy measure for capturing the underlying inflation. The Table 2.1 below captures the distinguishing features of headline and core inflation.

Table 2.1: Headline Inflation and Core Inflation: Some Distinguishing Features

Headline Inflation	Core Inflation
1. Is measured by rate of change of aggregate price index	1. Is measured by excluding temporary supply shock components and measures only demand pressure or permanent components of the aggregate price index.
2. Indicator of changes in the cost of living of people	2. Indicator of changes of monetary inflation
3. Is a measure of overall inflation trend	3. Is a proxy measure for underlying inflation trend
4. Captures ‘transitory’ or ‘noisy’ part of inflation also	4. Captures a notion of ‘trend’ inflation.
5. Constitutes permanent and transitory components of inflation	5. Inflation that is permanent and not transitory
6. Constitutes both anticipated and unanticipated part of inflation expectation	6. Is associated with anticipated components of inflation only.
7. Trade-off between headline inflation and unemployment rate in short-run exists due to either Friedman-Lucas price-surprise (unanticipated) or real-shock i.e. changes in relative prices that altered headline (measured) inflation in short-run.	7. No such trade-off exists because it eliminates unanticipated and relative price shock in measured inflation.

Source: Author’s own comparison

2.3 Measuring Core Inflation: Various Approaches

In the previous section, we reviewed various definitions of core inflation and also noted that the definitions of core inflation itself follow the abstract form of various methods by which core inflation is measured. Quah and Vahey (1995) definition point to use of econometric models which include other macroeconomic variables to produce an estimate of core inflation series whereas Bryan and Cecchetti (1993) definition of core inflation uses statistical method in which the existing price indices data are used to derive generalized trend inflation. Thus the methods used in estimating core inflation can be divided into two broad categories: the first is to use a theoretical model and the second is to directly use statistical methods. However, as noted in the introduction, the model-based measures of core inflation play a less significant role in the conduct of monetary policy than measures that use a statistical approach. Subsequent sections therefore focus in some detail on discussing the various statistical methods of core inflation.

Conceptual Framework for Statistical Measures of Core Inflation:

Under statistical approach, a number of methods of measuring core inflation have been proposed in the literature. These approaches use information either in term of the aggregate time-series of price index or disaggregate time series of price indices or exploiting the information of the cross-section of individual price changes of prices indices in each period. It is therefore, useful to discuss such statistical methods under a common conceptual framework.

Following Bryan and Cecchetti (1993) and Wynne (1999) notation, the growth rate of the price of i^{th} item (π_{it}) is decomposed into:

$$\pi_{it} = \pi_t^* + u_{it}$$

where π_t^* is the price change common to all items (common/persistence/ trend component), which is considered the best approximation of monetary inflation and

u_{it} is the relative price change regarded as noise resulting from idiosyncratic shocks to i^{th} item of aggregate price index

The objective is here to estimate π_t^* , the common component of all prices which Bryan and Cecchetti (93) defined as core inflation rate (linking with money growth rate as in the above definition) while Wynne (2008) explicitly interpreted it as the purchasing power of money. Since π_t^* is unobservable, it has to be derived from measured inflation π_t , which is in turn, the weighted sum of individual price changes with weight based on some notion of the cost of living theory-on the basis of expenditure share of average household budget for the i^{th} item:

$$\pi_t = \sum_i^n w_{it} \pi_{it}$$

Where n is the number of items in the commodity basket, w_{it} is weight of i^{th} item in time period t , and $\sum_{i=1}^n w_{it} = 1$

Expenditure based weights (w_{it}) are considered a poor approximation to measuring monetary inflation π_t^* . Wynne (2008) emphasized, that the weights should be based on a macroeconomic theory of the cost of inflation and not on microeconomic theory of the cost of living in order to produce a measure of monetary or core inflation. He argues that there is a fundamental contradiction in using the ‘cost of living’ weights to construct a ‘monetary’ measure of inflation. This can be seen, for instance, in the supply shock driven components such as oil and food prices, and which will be treated differently (different weights) in constructing core inflation index whereas in constructing standard aggregate price index these components are treated on the basis of their expenditure share in a representative (or average) household budget.

Besides this methodological argument, there is additional rationale for using a statistical approach for measuring core inflation. The basic statistics tells us that in the case of a population with normal distribution, a sample mean is an efficient estimator of the population mean. However, it is now well established fact that the distribution of price changes is very far from being normal distribution. many studies found at different time and across-country that the price distribution is skewed and leptokurtic, in such cases the

standard aggregate price index which gives equal importance (i.e. in calculating aggregate price index, weights are given on the basis of its expenditure) to each sample observation of price distribution may not provide optimal estimator of central tendency. It does not take account of the shape of the non-normality in price distribution, hence it does not yield best estimator of central tendency in class of other best estimators such as Limited Influence Estimator.

The statistical measures of core inflation are also a response to the above problems. They take an existing price index and then either remove certain volatile items from it on a basis of economic/statistical rationale (exclusion principle), or systematically (LIE -trimmed mean and median measures,), or re-weigh the components of that index depending either on its variability or persistency (volatile or less persistence items are down weighted and stable components are given relatively higher weights) or by dynamic factor analysis (derive weights based on common inflation signal relative to the noise in each individual inflation components), or by using trend methods to extract the ‘underlying’ trend components inflation from measured inflation (moving averages or smoothing or filter techniques). A statistical approach of measuring core inflation not only provides some solution to the methodological deficiency but also to statistical deficiencies of the conventional aggregate price index and postulates the concept of ‘monetary’ measure of inflation.

2.3.1 Exclusion Approach

The most common and also the initial approach to estimating core inflation is exclusion based core measures. The Bureau of Labor Statistics in the U.S.A. began in 1978 to report monthly growth of both the CPI and the Producer Price Index excluding food and energy (Rich and Steindel 2005). Such exclusion of certain commodities is based on the *subjective judgment (approach)*. Under this approach, certain components of headline index are excluded on the ground that their prices are considered to be most volatile, supply shock driven and administered and are, thus, beyond the control of central banks. Usual exclusions are captured under ‘Ex-food and energy’ strategy where existing index is reweighed by placing zero weights on these components and then remaining commodity groups are rescaled. Such subjective judgment of exclusion seems to be ad hoc but it does

follow some economic rationale particularly exclusion components are justified by its idiosyncratic volatility and the degree of control by the monetary authority.

There is also an “*objective approach*” for deciding which commodities to exclude. More specifically, criterion for exclusion of a commodity is its contribution of noise in the overall measured inflation. The noise or relative volatility of a component in measured inflation is either measured over the time or on a cross-section basis. Generally, the volatility is defined by the relative standard deviation (S.D) of an individual component in measured inflation.

Using exclusion principle, a wide range and types of commodities are considered for exclusion. (See table 2.2). Generally, exclusions seem to depend on countries specific circumstances or are data driven. For instance, for Canada, the eight most volatile components were selected along with indirect taxes, on the basis of its historical data characteristics (Macklem, 2001). The Bank of England excludes mortgage interest payment in headline inflation (retail price index, RPI). Further, the Bank of England uses the following three core inflation measures: the GDP deflator excluding export prices; RPI excluding import prices; and a measure based on unit labor cost. These core measures are useful for measuring the effect of an external shock. “Domestically generated inflation (DGI) may be viewed as a particular type of measure of core inflation that aims to exclude the one-off price level effects of movements in the exchange rate.” (Mankikar and Paisley, 2004, p.24).

The advantages of using this approach are: timely computation of core inflation, simplicity in computing, and its being readily understandable to public. Moreover, these measures are calculated on the basis of a pre-defined rule, which may result in enhanced transparency (Roger, 1998). For these reasons most central banks monitor exclusion based core measures.

The main disadvantage of this approach is that it *a priori* excludes certain items on once-for all basis, from price index on account that they are least informative price components for deriving core inflation. However, if the purpose of the core inflation measure is to reduce the level of noise that contaminates the signal, it must be recognized that this is done at the cost of the loss of information. The volatile components contain their own

noise as well as signal and excluding them means some of the latter is also lost. (Silver, 2007, p.169). Furthermore, especially in developing countries, a large expenditure of poorer sections of the society (and also their daily living) is closely linked with food and energy. Thus, Jalan (2002) correctly points out that in developing countries, a measure of core inflation excluding food items – which can account for more than half of the weight in the index – may not be very meaningful.

If exclusion core measures are based on some suitable criteria instead of a priori or subjective approach, then such measures are likely to be useful in enhancing credibility of monetary policy. Such criteria could be based on country specific circumstances or characteristics of the data.

2.3.2 Limited Influence Estimator (LIE) Approach

The limited influence approach has come after a series of work by Bryan and Pick 1991, Bryan and Cecchetti, (1993) and Bryan, Cecchetti and Wiggins, (1997) and Roger (1995 1997). This approach is different from the previous approach in the sense that it revises excluded commodities *in each period* on account of their ‘contribution to noise’ in measured inflation. Hence this method of constructing core inflation is more systematic than the previous one. It systematically excludes a percentage of each tail of the cross-section distribution of price changes (indicating extremely low price changes in the left tail and high changes in the right tail) and take 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 not be an outlier in succeeding period.

2.3.2.1 Theoretical and Statistical Justification of LIE

The use of LIE for estimating core inflation rate is generally supported in both economic and statistical sense. 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, rather than the estimator of measured inflation rate.

2.3.2.1.1 Theoretical Argument for LIE

The economic sense as noted above is grounded in the standard New-Keynesian two-sector model in which economy consists two types of price setter, sticky-price setters and flexible price setters. The latter set their prices in every period in response to realized changes in the economy. The former price setters set their prices infrequently and face potentially high Menu cost¹. These New-Keynesian type firms are bounded by contracts hence they have to take into account, while setting prices, both past mistakes and the expectation of future trends in the economy.

The first group price setters: the realization-based price setters create noise in the measured inflation as their price path exhibits transitory fluctuations because they can repeatedly and easily adjust their prices, there is no need for them to worry about the trend inflation or for that matter the growth rate of money supply. In contrast, the second group price setters: expectation based price setters would exhibit a smoother price path because any wrong decision will be costly for them. Therefore, with regard to core inflation, the second price setters should have useful information to quantify core or trend components of price change.

To demonstrate how Bryan and Cecchetti (1993)² have measured such core inflation through available data, we present the version of Bryan and Cecchetti (1993) model. This model takes place in a single period and there is a large number of firms which face the same ‘menu costs’ when adjusting their prices. Besides this, money supply is growing exogenously in a constant rate, $dM/dt = m$, velocity is constant and output growth is normalized to zero. Under these assumptions, in each period, firm will set the change of their price equals to m , so that inflation would be merely monetary inflation. Then the core inflation can be expressed as:

$$\pi^{core} = m$$

¹ Menu cost refers to what firms have to spend on setting and changing prices, when prices are changed.

² In general, for core inflation in relation to sticky price sector it does not matter whether it is LIE based core measure or exclusion based core measure but Bryan and Cecchetti, (1993) first linked its core inflation with sticky price sectors.

Following this initial price-setting exercise, each firm (i) experiences a shock (ε_i) to either its product demand or its production costs. In general, however, the distribution of shocks across firms may have any shape. After the shock is realized only firms for which $|\varepsilon_i|$ in absolute value exceeds the ‘menu cost’ will adjust their price. For these firms, the growth rate of prices π_i will be:

$$\pi_i = m + \varepsilon_i$$

If we assume that the level ($\bar{\varepsilon}$) at which firms decide to adjust their prices is the same, then the observed inflation rate will be:

$$\pi = m + \sum_{i=1}^n \left[\frac{\varepsilon_i}{|\varepsilon_i| - \bar{\varepsilon}} \max(|\varepsilon_i| - \bar{\varepsilon}, 0) \right]$$

where n is the number of firms in the economy. If the distribution is symmetrical, the second part on the right hand will be zero; but if it is positively (negatively) skewed, the aggregate inflation will be higher (lower) than the core inflation. Since, the difference between π and m arises from the tails of the distribution of (ε_i), therefore one way to reduce the impact of shocks on measured inflation is to use limited-influence estimators.

However, if there is an economy with fully flexible prices, “in such an economy, and with an unchanged monetary policy stance, a shock to a particular sector would lead to instantaneous changes in prices, which would leave the aggregate price level, and therefore the aggregate inflation rate, unchanged. In this type of world, it would make no sense to trim out large price movements (Zeldes-1994, cited in Mankikar and Paisley 2001, p.16 to17)

In this context, it is imperative to explain what are the implications of classical and Friedman view about supply-shock so that we might judge economic arguments for core inflation. In classical model, relative prices³ of commodities are determined by real factors i.e. each commodity price (π_{it}) is determined by its relative demand and supply forces in

³ Relative prices can be understood as follows. Let there be n commodities. Then relative price is price of a particular commodity relative to average price of all n commodities.

the real sector, while general price level (π_t) is determined by money supply. So given money stock any change in relative prices is not inflationary, because changes in relative prices are adjusted through increases in some nominal prices⁴ and decreases in some nominal prices. Thus micro-economic relative prices are determined by real factors while macroeconomic inflation determined by money supply via QTM or Cambridge equation: $m = kPY$, where m is the money supply, P the price level, Y the real output, and k the reciprocal of the velocity of money. In this way, classical doctrine postulates the principle of dichotomy between monetary sector and real sector, and that there is no correlation between relative prices and inflation rate. Similar logic was expressed by Friedman: he argued that if there is any change in relative prices due to shock such as drought leading to a sharp increase in price of food grain items, then consumer devotes more money on food items and so less would be spent on other items such as durable goods, whose prices therefore fall. In other words, due to substitution effect, drought simply results in changes in the relative prices of food items and other items within price index and general price is determined by money supply.

Nevertheless, Empirical studies in many economies have shown that there is a positive correlation between inflation rates and relative price variability. Among these Barro (1976) and Fischer (1981) studies are prominent. They present evidence of a significant relationship between relative prices and inflation rate, while Ball and Mankiw (1995) model and Balke and Wynne (1996) provide evidence of high correlations between observed mean inflation and the skewness.

Thus, in reality, the economy particularly in *short-run*, as noted above, constitutes a mix of both types of sectors i.e. New Keynesian two sector price setters. As a result price distribution is likely to exhibit non-Normality, and that relative price changes can affect the inflation rate.

⁴ Nominal price means, consumer paying price for purchasing a particular commodity.

2.3.2.1.2 Statistical Theory of LIE: 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 $\pi_{1t}, \pi_{2t}, \dots, \pi_{nt}$. Let the corresponding weights of these commodity groups in the total commodity basket be w_1, w_2, \dots, w_n respectively. We denote cumulative weight of commodity groups $1, 2, \dots, i$ as $W_i \left(= \sum_{k=1}^i w_k \right)$. If $\alpha\%$ is trimmed from each of the tails of this distribution, the interval $[\alpha/100, 1 - \alpha/100]$ 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 $I_\alpha = \{i \mid \alpha/100 \leq W_i \leq 1 - \alpha/100\}$. The $\alpha\%$ trimmed mean is given as:

$$\pi_{t\alpha}^* = \frac{1}{1 - 2\frac{\alpha}{100}} \sum_{i \in I_\alpha} w_i \pi_{it}$$

Here $\alpha\%$ 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 skewness 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 distribution⁵. 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

⁵ 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) examines efficiency of the 57th percentile core measure relative to the sample mean.

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 average of inflation does not guarantee that it is the best proxy for ‘true trend’ of inflation series on number of accounts⁶. 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 50th, 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 50th mean percentile and average mean percentile. They found that asymmetric trimmed means do not statistically exhibit a systematic bias relative to measured inflation rate.

⁶ See Marques *et al* (2000) for detailed argument.

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 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.

2.3.3 Reweighted Index Approach

This approach of measuring core inflation is based on reweighting of the whole price index at the disaggregated level such that the ‘signal’ or inflationary information in the data is maximized. Under this approach, three approaches within this criterion can be distinguished: one, use a variance (or standard deviation) criterion for reweighting subcomponents of aggregate index; two, use a persistence criterion; and third, derive a new weighting scheme based on common inflation signal relative to the noise in each individual inflation component.

2.3.3.1 Neo-Edgeworthian Index and Double Weighted index Method

This method chooses weights for the various individual prices that are inversely proportional to the volatility of those prices i.e. more variance less weight. This weighting scheme was investigated by Dow (1994), who termed the resulting measure of inflation a *Variance Weighted Price Index*, and by Diewert (1995), who called it *Neo-Edgeworthian measure of inflation*. Vega and Wynne (2001) applied the variance weighting scheme to the Euro price index data while Marques *et al* (2000), Heath *et al* (2004) derived weights by means of standard deviation of the change in relative prices.

The Bank of Canada computes a ‘double weighted’ core inflation measure. Under this

method each component of CPI is “double weighted, first by its expenditure share, and second by a measure inversely proportional to its variability. The second weight is defined as the reciprocal of the standard deviation of the change in relative prices, where the change in the relative price is measured by the difference between the price change of a component and the total inflation rate. These two weights are then multiplied. This measure includes all subcomponents at each period, thus reducing the possibility of excluding valuable information” (Armour, 2005, p.9 to 10).

The economic rationale in using such weighting scheme is that highly volatile prices are likely to contain more noise relative to the signal regarding underlying trend inflation. However, It is also difficult to compute and therefore its use as a communication measure.

2.3.3.2 Persistence Weighted Index Method

The persistence approach is due to Blinder (1997) comment on limited influence estimator. He defined core inflation as “the durable part or persistent component of aggregate inflation.” and added, that “.....the durable part of the information in each monthly inflation report was the part that was useful in medium and near-term inflation forecasting” (p.19). This is a forward looking approach to core inflation measurement. Blinder (1997) suggests a weighting scheme that goes directly with the strength of persistence of each component. This persistent weighting scheme was operationalized by Cutler (2001).

To estimate the persistence weights, Cutler ran an AR (1) model for 80 components of inflation series of Retail Price Index with exclusion of mortgage interest payments (RPIX) using monthly data for the U.K. coefficient thus obtained for each inflation series was used as scalar measure of persistence. If the coefficient of AR (1) is negative, it is taken as evidence of quick mean reversion in the respective component inflation rate which is consequently assigned a zero weight in constructing persistent core index. In other words, the components of negative coefficients are assigned zero weight on the grounds that it shows extremely low persistence. The positive AR (1) coefficient indicates the persistence of inflation series. Therefore with a positive AR (1) coefficient, its weight is simply assigned equal to the size of the persistence coefficient, (with all positive weights normalized to sum to unity). The weights are updated on an annual basis using recursive

regressions.

Such weighting scheme is different from Bryan and Cecchetti (trimmed mean) weighting scheme in which component prices are excluded from each tail of cross-sectional distribution because of their relative extreme variances or volatility at each time point whereas Cutler core inflation excludes those components which are found less persistent measured by its negative coefficient in AR(1) model. Cutler argues that persistent price changes carry more information about future inflation, and therefore should be given a high weight and those which have little or no persistence should be given low weights.

Demarco (2004) and Gupta and Saxegaard (2009) and other researchers have applied Cutler (2001) AR (1) persistence weighting scheme. Some other researchers have extended Cutler (2001) result, most prominently by Smith (2006) and Bilke and Stracca (2008). Bilke and Stracca (2008) examined three types of persistence measures to compute weights for core inflation measures: the sum of autoregressive coefficients, the mean reversion (primarily proposed by Dias and Marques, 2005) and correlation with future headline inflation as the measures of persistence. They consider the sum of autoregressive coefficients as measured by AR (p) model as the baseline persistence measure. The AR (p) model is a general form of Cutler restricted AR (1), whose order of process (p) is to be selected by information criterion.

The downside of such weighting scheme is that the types of products included and classification may change over the period in which weights are estimated. This gives rise to unstable coefficients (Silver 2008). Empirically persistence based core measure is found to be not so good. For instance Cutler (2001) found the persistent weighted core measure is ranked third among seven core measures in terms of predictive ability.

2.3.3.3 Dynamic Factor Index Model

Another approach to measuring core inflation is Dynamic Factor Index (DFI) Model - first used by Bryan and Cecchetti (1993). This approach utilizes information on both cross-sectional and time series of disaggregated components inflation of aggregate price index. The DFI model proposed a new weighting scheme which is based on common inflation signal relative to the noise in each individual inflation component. In this approach, each individual component inflation rate is viewed as the sum of a common inflation element

termed as monetary inflation and idiosyncratic relative price element. The common inflation element in all price changes is identified by assuming that it is uncorrelated with relative price changes at all leads-lags and then estimate of DFI is obtained by using Kalman filter method.

Despite the DFI advantage in using-both cross-sectional and time-series information of inflation data, the application of DFI is less often implemented in the literature. Since like other econometric model based core measures, each time new observation arrives- history of DFI estimates will change. This approach reduces bias in the inflation measure but does not eliminate noise.

2.3.4 Univariate -Trend Approach

The trend approach is the simplest form of eliminating ‘noise’ components either at disaggregated level or at aggregate level. This is used to identify the trend estimate of a measured inflation series. The trend estimates are also used for choosing alternative competing core inflation measures on the basis of their deviation from trend series.

Time-series inflation is in general, constituted by trend, seasonal and irregular components and it is the trend component which is crucial for monetary policy. To extract trend component from inflation data, several trend estimate techniques have been proposed in the literature, for instance seasonal adjustment techniques such as X-12 ARIMA, Tramo Seats or trend extraction methods such as simple moving average techniques or more sophisticated smoothing techniques such as H-P filter, ARIMA model based procedures etc. Along this line, Cogley (2002) developed a core inflation measure involving the exponential smoothing of current and past aggregate price changes. This measure can be motivated by appealing to the idea that the government and private sector use adaptive methods to learn about a world in which there are occasional regime shifts in mean inflation (Rich and Steindel, 2005, p7). This exponential measure has a number of advantages as explained by Cogley (2002) that:

“...unlike many other approximations to low-pass filters, such as those advocated by Baxter and King (1999) or Hodrick and Prescott (1997), this filter is one sided into the past and can be implemented in real time. As Bryan and Cecchetti note, two-sided filters are less useful to monetary policy makers because they reduce the timeliness of incoming

inflation data. In contrast, this filter is one-sided into the past, so its output would be available to policymakers as soon as new inflation data became available. Third, this measure is absolutely trivial to compute and depends on only one free parameter, g_0 , which can be calibrated a priori. Among other things, this means that the filter coefficients need not be reestimated when new data arrive and that the history of the core series need not be revised in response to changes in parameter estimates” (p.102 to 103).

Although trend approach is easy to use but filtering technique is purely ad-hoc and there is no economic interpretation for this. The same criticism is true for seasonal factor as it deals with only seasonality⁷, and its adjustment is unstable to filter irregular price shock. Also it is not available in a timely fashion. Thus, in spite of its easiness and efficiency in eliminating some part of transitory noise, the result lacks acceptance especially in terms of economic interpretation and policy implication.

2.3.5 Multivariate Modeling Approach

One element that is common to all approaches to core inflation examined so far is that they use only price series data i.e. the univariate nature of these core measures. By contrast, there are also multivariate models which typically use other monetary variables to derive core inflation. Such model based approach is appealing to the central bankers because it goes directly to monetary theory in the sense that the estimation of core inflation is derived from other macro variables. This attempts to establish a link between core inflation and its underlying economic determinants most importantly monetary policy variables. Identification of such a link then provides a rationale why monetary authorities should care about core inflation, and it also helps in understanding the extent to which they can control it. This approach was first developed by Quah and Vahey (1995) who define core inflation as the component of measured inflation that has no impact on real

⁷ Recently, The RBI Internal Technical Committee on “Seasonal Movements in Inflation” (May, 2008) reported that even seasonally adjusted data on month-over-month inflation exhibit high volatility. Similarly moving averages of price indices of previous 4/12/52 weeks have problem of being biased towards past data. Such measures of inflation rate become less useful for measuring current underlying inflation. Further, the Report used the X-12 ARIMA procedures for obtaining seasonal factors of WPI and CPI series during the year. However, as noted above it adjusts only seasonality and is deficient in dealing with irregular price shocks.

output in the long run. What motivates this definition is the vertical long run Phillips Curve. Their measure is constructed by placing long-run restrictions on a bivariate VAR system for output and inflation. This system is assumed to be driven by two independent types of disturbances. The first disturbance - the core shock - has no impact on real output in the long-run. The second disturbance - the non-core shock - is not restricted at all. This allows them to test whether the non-core shock has permanent effects on inflation or not.

Other researchers expanded this approach incorporating other macro variables with different identification and specification schemes in a multivariate SVAR model such as Blix (1995), Folkertsma and Hubrich (2000), Bjørnland (2001), Baglino and Morana (2003) etc. Blix (1995) includes the cointegration relationship between the money stock, prices and output in a VAR model in the calculation of the core inflation rate. They find, in general, that there is little difference between the core inflation measure resulting from the bivariate VAR and the one resulting from multivariate VAR.

This approach is useful on grounds that it is based on monetary theory and that it is forward looking in nature. In spite of this advantage, this approach has been criticized on other grounds. One important criticism is that each time as new observation arrives - history of model estimates will change. It is difficult to understand for the public. Another problem with this approach concerns the specification and identification schemes for deriving core inflation with SVAR model. As a whole, the sensitivity of the results would undermine the credibility of the core measure with the public and make it unsuitable as a target for policy, particularly since it is likely that a core inflation series based on an economic model would be generated directly by the policy-maker rather than by a statistical agency. These features limit use of these measures as indicators of core inflation.

Table 2.2: Summary of the Official Core Inflation Measures Adopted by some Countries as well as the other Core Inflation Measures used internally by their Central Banks

Country	Official Core Measure	Other Measures Used Internally by Central Bank
Canada	CPI excluding Food, Energy and Indirect Taxes	CPI excluding 8 most volatile items(16%) Weighted Median Trimmed Mean (15%)
Thailand	CPI excluding Fresh Food and Energy (23%)	Trimmed Mean (10%)
Australia	Treasury underlying CPI	Trimmed Mean Weighted Median
New Zealand	CPI excluding interest charges	
Singapore	CPI excluding costs of private road transport and costs of accommodation	CPI excluding volatile items (30%) Weighted Median Trimmed Mean (15%) Structural Vector Autogegression (VAR) model estimate
Japan	CPI excluding Fresh Food	
Peru	CPI excluding 9 volatile items (Foods, fruits and vegetables, and urban transport, about 21.2%)	
United State	CPI excluding food and energy	
United Kingdom	Retail price index excluding mortgage interest rates (RPIX)	Weighted median Trimmed mean (15%)
Chile	CPI excluding 20% with higher (-) variations and 8% with higher (+) variations	
Germany	CPI excluding indirect taxes	
Spain	CPI excluding energy and unprocessed food (IPSEBENE)	
Netherlands	ULI minus fruits, vegetables, and energy	
Portugal	CPI (ULI) less unprocessed food and energy	

Source: Department of Labor and Employment Manila, Philippines *Bangko Sentral ng Pilipinas (BSP)*. Vol. 9 No. 30, August 2005

2.4 Framework for Assessing Core Inflation Measures

2.4.1 Desirable Theoretical Properties of Core Inflation Measures

Roger (1997, 98) discussed various desirable properties of core inflation as follows. The core inflation index should be,

- **Timely:** The measure should be available in a timely manner. If the measure is only available with a long lag, that will reduce its value to the policy makers. Timeliness is also important if core inflation is used to explain monetary policy measures to the public
- **Verifiable and credible:** The measure of core inflation should be verifiable i.e. it should be possible that it should be calculable by any one other besides its originator. Otherwise it would not be good credible.
- **Unbiased:** The difference between the average rate of inflation of core measure and the headline measure should be zero over a long period of time, since any difference will provide false signals which again reduce the credibility of the measure.

Wynne (1999) agrees with these criteria and proposed the following set of criteria:

- The measure should be computable in real time.
- The measure should be forward looking in some sense.
- The measure should have a track record of some sort.
- The measure should be understandable by the public.
- Its history does not change each time when obtained a new observation.
- The measure should have some theoretical basis, ideally in monetary theory.

Given lack of a single core measure, the above criteria are important in defining useful core inflation measures. So far they are normative; no empirical specifications have been specified as consequence the above criteria have been augmented by various empirical tests/criteria/ one way or another. Different types of empirical tests have been evolved in the literature.

Further, the above criteria for good measure of core inflation are not absolute. There may be trade-off between these properties. It is possible that different policymakers might be applying different priorities to each of the criterion. Cutler (2001) point out that the weight

to each criterion will depend on the intended use of the core inflation in the monetary policy. The use of core measures can conceptually be distinguished based on the type of framework or objective function that central banks adopt in practice. For instance, if central bank operates under explicit inflation targeting framework, core measures can be used either as an indicator of current and future trends in inflation, or as a viable target for monetary policy. (Hogan *et al* (2001). For the use of core inflation as target variable, Roger (1998) points that core inflation should be credible, understandable, and computable in real time and not subject to revision. Even if a central bank operates under dual or multiple mandates, price stability is almost always one of the main objectives in the conduct of monetary policy. Therefore the potential use of core inflation can be an indicator of current and future trends in inflation. To be more precise, given the monetary transmission lag, measures of core inflation can be used in day-to-day price development analysis in order to track the inflation trend path and to assess future inflation path. Core inflation can also be used to guide or set policy instruments to achieve the objectives of monetary policy. In short, for core inflation as a policy tool in the process of monetary policy formulation, it is essential that core measures should be unbiased, stable, less volatile, and good trend or attractor of headline inflation and a predictor of headline inflation and should correlate closely with monetary variables. In short, the properties of core inflation measure can be assessed on the basis of its use or propose in the conduct of monetary policy framework.

Bilke (2006) set explicitly a framework in which he first assigned three goals to core inflation and then described expected empirical properties to each of the three goals; accordingly he assessed the empirical properties of core inflation relative to their assigned goals. Following Bilke (2006), the uses of core inflation and its expected empirical properties can be set as follows.

- a) a descriptive tool -analyzing descriptive statistics of core inflation measures
- b) an indicator of trend inflation or an attractor for headline inflation-examining trend and attractor properties of core inflation measures
- c) a predictor of headline inflation developments *or* a leading indicator of headline inflation /information on the outlook for inflation.)-an examining predictive ability of core inflation measures

d) In the literature, apart from the above set of criteria, core inflation is a useful policy input in the process of monetary policy formulation, it is also important to investigate relationship between alternative inflation measures and monetary policy.

2.4.2 A Review of Empirical Criteria for Assessing Core Inflation Measures

2.4.2.1 Descriptive Statistics and Ability to Track long term Trend Inflation

A useful core inflation measure can be expected to have a mean⁸ similar to mean of headline inflation and it would be more stable and less volatile than headline inflation. Specifically, core measures can be evaluated on the basis of its accuracy to track long term trend inflation .i.e. deviation between the two series should be minimized. For doing this, there are some statistical methods such as similarity in mean inflation rate of core inflation and headline inflation or to examine relative standard deviation, coefficient of variation, standard deviation of the first difference of the inflation rate as a measure of high-frequency volatility. An important method is to compute root mean square error (RMSE) or/and mean absolute deviation (MAD). To compute the root mean squared error (RMSE) of the difference between trend inflation and core inflation; we have,

$$RMSE^{Core} = \sqrt{\left\{ \frac{1}{T} \sum (\pi_t^{Trend} - \pi_t^{Core})^2 \right\}} \quad (2.1)$$

Where π_t^{Trend} is an estimate of the trend of inflation at time t and π_t^{Core} is a particular measure of core inflation at time t .

In order to evaluate alternative core measures, these criteria have been used to trace the ability of core measures in tracking some benchmark ‘reference’ trend series of headline inflation. Chosen benchmark- reference trend series are thought to be a good proxy for underlying inflation trend in the economy. In the literature a number of proxy measures have been used for benchmark reference series, For instance;

- Three year averages of headline inflation (Clark, 2001).

⁸ A similarity of the means is rather a test of unbiasedness of the core measures since attached importance to unbiasedness property that core measures should be statistically unbiased with headline inflation.

- 36 -month central moving average (CMA) of actual inflation (Bryan *et al.*, 1997 Vega and Wynne (2001), and number of other researchers).
- The Baxter-King band-pass filter series together with 36 -month central moving average, and 24-month forward moving looking average (Dolmas 2005)
- The Baxter-King band-pass filter series (Rich and Steindel 2005).
- The Hodrick-Prescott filter series (Vega and Wynne 2003)
- The Hodrick-Prescott filter series together with 24-month, 36-month and 48-month centred moving average of inflation rate (Piotr Wiesiolek and Anna Kosior 2009)
- Kalman filter of the long-run component of inflation (Vargas *et al.*, 2009)

Although all these reference trend series can be good proxies of underlying trend inflation, it has problem with end-points sample. These two sided filters series need data on time ‘t-n’ and also ‘t+n’ in order to get estimate at time ‘t’, as a result it can not be implemented in real time and so it can not be used as useful core inflation measures. Nevertheless, the basic idea behind the use of the reference measures against various core measures being evaluated, as Vega and Wynne (2003) explained, is to see to what extent various core inflation measures have information on underlying trend inflation which is available in real time⁹. Further, using benchmark- reference trend measure such as CMA in assessing core inflation measures has intuitive interpretation and easy to implement.

Yet there has been some criticism to use this criterion as yardstick to evaluate alternative core inflation measures. First, the benchmark references like CMA series suggested by Bryan *et al* (1997) is empirically found sensitive with degree of smoothness of series. Second, as noted previously, Marques *et al* (2000) argue that the benchmark-reference trend measure does not guarantee that it is the best proxy for ‘true trend’ of inflation series. Therefore in this approach, it also does not guarantee that the chosen core measures are true representative of underlying inflation series. Marques *et al* (2000) instead propose a set of three necessary and testable econometric tests and argue that any underlying inflation measures can be used as useful core measures if they satisfy the proposed three necessary conditions.

⁹ The reference trend measures in RMSE approach is also used to find optimal trimming percentage. (see the section 3.2.1).

2.4.2.2 Unbiased, Attractor and Exogeneity (UAE) Tests

Marques *et al* (2000) proposed a set of three econometric tests. They consider that these three tests are necessary conditions, and that any useful core inflation measures should satisfy them,

(i) If headline inflation, π_t is I (1), then core inflation, π_t^* has to 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.

(ii) There should be an error correction mechanism which is given by $z_{t-1} = (\pi_{t-1} - \pi_{t-1}^*)$ for $\Delta\pi_t$,

$$\Delta\pi_t = \sum_{j=1}^m a_j \Delta\pi_{t-j} + \sum_{j=1}^n \beta_j \Delta\pi_{t-j}^* - \gamma(\pi_{t-1} - \pi_{t-1}^*) + \varepsilon_t \quad (2.2)$$

and the null hypothesis $\gamma = 0$ should be rejected.

(iii) π_t^* should be strongly exogenous for the parameters in the above error-correction equation. This implies that in the error-correction model for π_t^* ,

$$\Delta\pi_t^* = \sum_{j=1}^r \delta_j \Delta\pi_{t-j}^* + \sum_{j=1}^s \theta_j \Delta\pi_{t-j} - \lambda(\pi_{t-1}^* - \pi_{t-1}) + \eta_t \quad (2.3)$$

and the hypothesis $\lambda = \theta_1 = \dots = \theta_s = 0$ is accepted.

where m and n in equation (2.2) and r and s in equation (2.3) are number lags for headline inflation and core inflation respectively and ε_t and η_t represent error terms.

Some details are warranted on the above conditions. The first condition implies that there must not be any systematic divergence between core and headline inflation. Marques *et al* (2000) emphasize that if $\varepsilon_t = (\pi_t - \pi_t^*)$ does not have zero mean ($E(\pi_t - \pi_t^*) \neq 0$) both variables do not have same mean, then core inflation can not be capturing the permanent or persistent component of headline inflation therefore such measures would be biased. The condition (i) is thus a test of unbiasedness property of core inflation. In the literature many researchers for instance Heath *et al* (2004), Ivan Roberts (2005) etc. - consider the

unbiasedness condition as essential that any core measures should satisfy.

In case headline inflation (π_t) is integrated of first order I (1) i.e. is non-stationary, then considering single equation approach¹⁰, the tests for condition (i) is carried in two stages: in first steps conduct unit root test on $\varepsilon_t = (\pi_t - \pi_t^*)$ for testing its stationarity. More specifically ADF test with constant for ε_t is:

$$\varepsilon_t = a_0 + \delta\varepsilon_{t-1} + \sum_{i=1}^p \beta_i \Delta\varepsilon_{t-i} + \eta_t \quad (2.4)$$

If ε_t found stationary, then second stage is to check whether the constant term in the above ADF equation is significant or not i.e. to see whether the hypothesis $a_0 = 0$, using a simple t-test.

If headline (π_t) is found to be I (0), then headline 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. To test this condition Marques *et al* (2000) have proposed testing the restrictions $a_0 = 0; \beta_1 = 1$ on the static regression:

$$\pi_t = a_0 + \beta_1 \pi_t^* + u_t \quad (2.5)$$

Core inflation indicators that pass this test are unbiased estimators. As noted above, Heath *et al* (2004) and Ivan Roberts (2005) and others consider unbiasedness as an essential property of core inflation. Heath *et al* (2004) and Ivan Roberts (2005) found inflation is stationary in Australia. They therefore test the unbiasedness property using equation as in (2.5). Heath *et al* consider Granger causality tests¹¹ as a second empirical criterion while

¹⁰ To check robustness, Marques *et al.* (2003) also carried out an analysis using the Johansen approach. The results were, nevertheless similar to ones with obtained from the Engle-Granger single equation approach.

¹¹ Note that even if headline is stationary, it is useful to adopt ECM since it capture short-term dynamics relationship between core and headline, further the objective in ECM approach, is to see whether or not former are attractor for latter specifically to gauge to what extent core attractor of headline through coefficient of error correction term in (2). If it is found vary close to negative -1, rapid or speedy convergence of headline to core can be interpreted. Such coefficients of course one could expect if both headlines and core are stationary variables. Moreover, testing coefficients of error correction term is special case of granger type causality test. This has been explained by Marques *et al.* (2000) that the “condition ii)

Ivan Roberts, instead of Granger causality tests, estimates Gap tests similar to equation (2.9) and (2.12). Nevertheless, Ivan Roberts (2005) showed that Gap tests are comparable to Granger type tests with certain coefficient restrictions¹². Both authors consider that their two tests are essential for any desirable core inflation measure.

Turning to Marques *et al* second condition which implies that the error correction equation exists for headline inflation (π_t). This means that in the long run headline (π_t) must converge to core (π_t^*) and short run adjustment via error correction term allow headline inflation to converge to core inflation. The argument is that if headline inflation is above core inflation, then it is expected that headline inflation will sooner or later start to decrease and will converge to core inflation. This suggests that core act as an attractor for headline. The condition (ii) also implies that core inflation Granger causes headline inflation through the error-correction term. The condition (ii) is thus to test attractor property of core inflation by simply testing significance of error term coefficient in the equation (2.2). Marques *et al* (2000) emphasis that if γ is insignificant, then there is no point in knowing whether in a given period π_t^* is above or below π_t .

The condition (iii) requires that an error correction representation does not exist for core inflation. This means that condition (iii) prevents condition (ii) which might occur in the other way. To be more precise, headline should not be an ‘attractor’ for core inflation. Accordingly, equation (2.3) is the test of exogenous property of core inflation. If the coefficient of the error-correction term (λ) is insignificant, it then establishes weakly exogenous property of core inflation and to establish strong exogeneity property, equation (2.3) must have $\lambda = \theta_1 = \dots = \theta_s = 0$. In other words, strong exogeneity requires that equation (2.3) must not have error correction term (i.e. $\lambda = 0$) and also headline must not

includes as a special case the requirement of Granger causality. In particular, this condition requires that π_t^* Granger causes π_t , i.e., that π_t^* is a leading indicator of π_t . However, condition ii) goes beyond this requirement by requiring the existence not only of the “short-term” causality, reflected in equation (2.2) by the term $\sum_{j=1}^n \beta_j \Delta \pi_{t-j}^*$, but also (and mainly) of a “long-run” causality reflected in equation (2.2) by the error correction term” (p.6).

¹² see for detail in Ivan Roberts (2005, p.14)

Granger cause core inflation ($\sum_{j=1}^s \theta_j = 0$). Marques *et al* (2000) argue that if headline inflation was an ‘attractor’ of core inflation, it would be more difficult to infer anything about the future path of headline inflation by looking at core inflation rate, since the relationship would run both ways.

Marques *et al* (2000) acknowledged that before them, Freeman (1998) had first proposed the Cointegration idea. Freeman applied cointegration (using Engle-granger single equation approach) and granger causality tests (through VECM) for core inflation measures. He argued that if inflation is I (1), then core inflation also to be I (1) and cointegrated with headline inflation such that $\varepsilon_t = (\pi_t - \beta \pi_t^*)$, if and only if there exists some unique β . Making similar assumptions, Ribba (2003) and Dixon and Lim (2004) also implement a test similar to the Marques *et al* tests. However, there are some differences in Marques *et al* (2000) and Freeman (1998) approach to test criteria. Marques *et al* (2000) argue that Granger causality test should be seen as a special type of case in their tests and point out that condition (ii) equation (2.2) should not be interpreted as a test of the ability of core inflation to forecast future inflation. Contrary to Marques *et al.*, Freeman (1998) estimates the error correction models with contemporaneous values of the right-hand side variables (i.e. Freeman does not impose the unity restriction on cointegration parameters in equation 2.2 and 2.3) and focus explicitly on forecasting performance of core measures. However, Marques *et al* (2003) argue that “by definition, a good predictor of future inflation must be able to account for short-term movements on the price level, but this is exactly what we cannot or should not expect from a core inflation indicator, as it is just a summary measure of the long run characteristics of inflation” (p. 768).

A number of researchers have applied these tests on different core measures; see for example Mankikar and Paisley (2004), Mykhaylychenko and Wozniak (2005), Gupta and Saxegaard (2009), and Wiesiolek and Kosior (2009) etc.

However, these tests are not without their problems. Mankikar and Paisley (2004) put forward the problem as follows “suppose the target for monetary policy was to keep annual CPI inflation to some prescribed path, for example 2% at all times. And suppose

that, over the sample period, policy had been used actively, and set optimally to achieve the target. Then, CPI inflation would simply follow the prescribed path, save perhaps for some unavoidable and unforecastable error. If we were to perform Marques *et al*'s tests on a measure of core inflation, it would fail conditions (ii) and (iii). That is, CPI inflation would not be attracted to the measure of core inflation since it follows the exogenously prescribed path, but core inflation would be attracted to CPI inflation. This finding would cause us to reject this measure of core inflation as useful in providing forward-looking information about the future path of CPI inflation, even though it might well be useful in setting policy. Thus, failure in the tests does not necessarily mean that a measure of core inflation is not informative-it may just be that the effects of past policy mean that Marques *et al*'s tests do not help us make that judgment" (p.27). Other than the institutional framework of monetary policy, such possibility is likely in stable and low inflation environment, where monetary authority are mostly able to maintain its tolerable inflation target. It is therefore, imperative to look at some other tests such as ability of tracking trend inflation vis-à-vis Marques *et al* tests to further assess core inflation measures.

2.4.2.3 Predictive Ability

Many researchers agree that, in addition to accurately tracking trend inflation, a useful core measure should predict future headline inflation. According to Blinder (1997), a key selection criterion for a core inflation rate is its information content with regard to future measured inflation. Nevertheless, there are some arguments against using forecasting ability as a yardstick to gauge a usefulness of a core inflation measure.

One argument is that the observed movements in aggregate inflation often reflect transitory, non-monetary forces, so that central banks should just restrict their attention to the underlying trend in inflation. Another concern relates to the basic difficulty of forecasting inflation. Relationships that appear to satisfactorily predict inflation in one year will often deteriorate in the next (Rich and Steindel, 2005). Marques *et al* (2000), as mentioned above, also criticized testing predictive power of core measures. Despite such disagreement about predictive ability criteria, a number of researchers have been using predictive ability as the sole criteria to choosing among alternative core measures. Measures of core inflation that pass this test are considered suitable from a central bank

point of view. For testing predictive ability of core measures, there have been different model specifications used in literature.

(a) Univariate and bi-variate Models:

Bryan and Cecchetti (1993) used a simple regression model of CPI on different core inflation estimates and CPI itself to see which of them forecasts CPI inflation best at horizons of one to five years. Their estimated regression is similar to:

$$\pi_{t+h} = \alpha + \beta \pi_t + \varepsilon_{t+h} \quad (2.6)$$

where π_t is the one of the inflation measures viz., all items CPI, CPI excluding food and energy, the weighted median, and the 15 percent trimmed mean, h is the forecast horizon. They estimated the regression from monthly data from February 1967 to December 1979, and then they used fitted regression to calculate RMSEs for forecasts beginning in January 1980 over future annual periods between one and five years. Similar univariate type model (6) was estimated by Blinder and Reis (2005) and Khettry and Mester (2006). They examined whether core is a better predictor of future inflation than headline inflation itself for the U.S data. Khettry and Mester (2006) examined the predictability of headline inflation over 6, 12, 24, and 36 months forecasting horizons, using as the explanatory variables either the 12-month change in headline inflation, or the 12-month change in core inflation measures. Then they compare the accuracy of both in-sample and out-of-sample forecasts. They reported the in-sample forecasting accuracy by means of the standard errors of the forecast equations which was estimated using the data from August 1987 through December 2005. For the out-of-sample forecasting accuracy, they reported the root mean squared errors (RMSEs) of the forecasts from January 1996 through December 2005 that were generated from estimated equation on the data from August 1987 through December 1995.

The above model can also be augmented by lags i.e. by using as an auto-regressive AR (p) form. Similar to the above, the results of adjusted R square (\bar{R}^2) for headline inflation can then be used as benchmark against which various individual core inflation measures would be compared. Also forecast accuracy can be executed within sample and out of sample forecast.

Lafèche (1997) and Hogan *et al* (2001) considered equations of the following form:

$$\pi_t = \alpha_0 + \beta_1 \pi_{t-12} + \beta_2 \pi_{t-1}^* + \varepsilon_t \quad (2.7)$$

where π_t^* is one of the core inflation measure.

In order to assess whether the different measures of core inflation can provide additional information on forecasts of headline inflation. In other words, they examine marginal forecasting power for different measures of core inflation over and above the information that already contained in the past changes in the headline itself. Accordingly, they then selected the core inflation measures with the highest \bar{R}^2 .

An alternative formulation to the above equation (2.7) with a more general specification is used in Cutler (2001) and Catte and Sløk (2005). Their specification is in the form of a distributive model:

$$\pi_t = \alpha_0 + \sum_{i=1}^m \beta_{1i} \pi_{t-i} + \sum_{i=1}^m \beta_{2i} \pi_{t-i}^* + \varepsilon_t \quad (2.8)$$

Then statistical tests (F or Wald tests) are conducted to see if the sum of the $\sum_{i=1}^m \beta_{2i}$ parameters were positive and significant as a group. The \bar{R}^2 for those significant specifications are then utilized in order to assess contributions of predictive power of lagged individual core inflation over and above that of lagged headline inflation. Again one can go for in sample and out of sample forecasting accuracy at various horizons.

Bihan and Sédillot (2000, 2002) used standard bivariate VAR models, including headline inflation and each core inflation indicator, to assess forecasting accuracy of four alternative core inflation indicators for French data. Bihan' and Sédillot (2000) particularly perform the D.M (Diebold and Mariano 1995) test to compare forecast accuracy between VAR model and forecast of the benchmark model chosen as an autoregressive (AR) model of headline inflation at various horizons.

(b) Gap Test Model:

One common approach is often used in literature, was proposed by Cogley (2002) Clark (2001) and others is that if current headline inflation differs from the underlying core

inflation rate, headline inflation should move towards core inflation rate. When current overall inflation is below core, overall inflation should rise. To assure this, Clark (2001) and others used regressions of the change in headline inflation from today to some point in the future $(\pi_{t+h} - \pi_t)$ on the current gap between core and overall inflation. More specifically Clark (2001) estimates the following regression form:

$$(\pi_{t+h} - \pi_t) = \alpha_h + \beta_h(\pi_t^* - \pi_t) + \varepsilon_{t+h}, \quad (2.9)$$

where h represents the in-sample forecast horizon with $\varepsilon_t \sim (0, \sigma^2)$

Clark (2001) argues for his model that it is consistent with the beliefs of some policymakers and commentators who take movements in core inflation, by themselves, as signals of future changes in inflation. Similar type of regression model (9) has been used in studies such as Hogan *et al* (2001), Macklem (2001), Cutler (2001), Cogley (2002), Catte and Sløk (2005), and Rich and Steindel (2005), Armour (2006), Armas *et al* (2009), Vargas *et al* (2009), etc. It should be noted that Clark (2001), Cogley (2002), Rich and Steindel (2005) and others used the Newey-West (1987) HAC covariance matrix to form the standard errors and the test statistics for equation (2.9). In the process of the construction of the variables used in the regression which includes the h-period in-sample forecast horizons, the Newey-West (1987) HAC is used to account for autocorrelations caused by the overlapping time period of variables and any potential conditional heteroskedasticity (Rich and Steindel 2005).

The above model has a number of attractive features. First, being a simple specification it is easy to interpret and second, it can be used (interpreted) in two ways viz., testing attractor property of core measure and ability of forecasting future transient movement in headline inflation. The intuitive explanation (or interpretation) of the above specification can be put in this way: Suppose in period t inflation figure for headline and core are 10% and 8 % respectively. The 2% inflationary gap in period t is then said to be ‘noise’ or transitory disturbance components if and only if headline inflation tends toward core inflation rate i.e., 8% in period $t+h$. Analogously in reverse case, the 2% inflation

difference in period t is said to be temporary inflationary difference¹³ if and only if headline inflation will move toward core inflation i.e., at 10% in period $t+h$. Thus, in above regression, the ‘if and only if’ condition can be tested by testing restrictions $\beta=1$ and $\alpha=0$. If β is less than one, then it understates the transitory movements; if it is greater than one, then it overstates the transitory movements. This test captures the extent to which transient movements reverse toward core inflation after shock to headline inflation. Moreover, if β found very close to zero or statistically insignificant, then it suggests that what are excluded from a representative core measure, are not temporary volatile components, instead they are persistence components¹⁴ (also imply that representative core inflation measures exclude inflationary signal from inflation data) which create the divergence between core and headline inflation series. This is what core inflation series are not supposed to do, and in any case it does i.e. excludes persistence components, then it can be concluded that such core measures are not suitable to be useful core or trend inflation measure.

Since the coefficient α captures the systematic bias in the measure, the joint restriction $\alpha=0$ and $\beta=1$ also indicates that core inflation is an unbiased predictor of headline inflation over h period forecast horizon. To demonstrate how equation (2.9) is a test for unbiased predictor of headline inflation, suppose that $\alpha=0$ and $\beta=1$, then equation (2.9) collapses to:

$$\pi_{t+h} = \pi_t^* + \varepsilon_{t+h} \quad (2.10)$$

with $E(\varepsilon_t) = 0$, the interpretation of $\beta = 1$ is

¹³ Here 2% inflation difference in period t may arise from negative temporary supply shocks factors that will be reversed in period $t+h$. Alternatively, it indicates that the inflation pressure which reflected in core inflation (here 10%) in period t , may arise from persistence factors such as consistently high global oil prices (due to consistent high demand for oil at global level as results of increasing aggregate demand in emerging economies) but due to administration of such prices in domestic economy, headline inflation can be at 8% in period t . However, once administrative prices are revised to upward then current headline inflation will likely to converge core inflation in period $t+h$. Hence, core inflation can also be represented as a measure of inflation pressure.

¹⁴ On this line of reasoning, equation (2.9) can also be used to assess persistency of individual components of headline index.

$$\beta = \frac{\Delta(\pi_{t+h} - \pi_t)}{\Delta(\pi_t^* - \pi_t)} = 1$$

$$\Delta(\pi_{t+h} - \pi_t) = \Delta(\pi_t^* - \pi_t)$$

$$\Delta\pi_{t+h} = \Delta\pi_t^* \quad (2.11)$$

with $E(\varepsilon_t) = 0$, and $\alpha = 0$; $\beta = 1$ equation (2.11) thus states that core inflation is an unbiased predictor of headline inflation. Further, assuming inflation is stationary process, then although core deviation may not be capturing all transitory movement in headline deviation but it provides in period t , ‘mean’ forecast of headline deviation of h -period horizon.

Consequently once restriction $\alpha = 0$ and $\beta = 1$ in equation (2.9) is statistically tested then core inflation possesses some information about future movement in headline inflation and this proportion of information, in terms of R^2 , can be gauged among alternative core inflation measures.

Some researches estimate equation (2.9) by replacing core deviation for headline deviation as a regressand in order to assure that headline inflation is not acting as a attractor of representative core inflation i.e. to see, whether core inflation adjust towards headline inflation?

$$(\pi_{t+h}^* - \pi_t^*) = \alpha_h + \delta_h(\pi_t^* - \pi_t) + \eta_{t+h} \quad (2.12)$$

Researchers may mutually estimate (2.9) and (2.12) by OLS. If individual OLS estimates of equation (2.9) and (2.12) show β is significant or close to 1 and $\delta = 0$ or insignificance respectively, then it can be concluded that headline inflation tends to adjust towards core inflation, but not vice versa. However, Marques *et al* (2000), as discussed above, proposed a set of necessary tests which are more general form of the Gap tests described here in the (2.9) and (2.12). They particularly augmented the Gap tests for dynamics in form of the error correction models (see equations (2.2) and (2.3)).

(c) Models with macro-monetary variables:

Many researchers have extended a univariate forecasting model into multivariate Gap model in order to assess marginal forecasting power in terms of R^2 of each inflation measure to forecasting headline inflation. They measured this. For instance, Cogley (2002) and Rich and Steindel (2005) included other macro variables which they consider to have additional predictive power content for movement in inflation. Rich and Steindel (2005) extended equation is:

$$(\pi_{t+h} - \pi_t) = \alpha_h + \beta_h(\pi_t^* - \pi_t) + \gamma_h X_t + \varepsilon_{t+h} \quad (2.13)$$

Here X_t is a macroeconomic variable that is taken as an indicator of economic slack in the economy. Macro indicators included are: unemployment rate, capacity utilization and the output gap.

Bryan and Cecchetti (1993) also estimated multivariate model (by including macro variables) particularly to assess marginal forecasting power of alternative core measures. They included variables, such as monthly lags of M1 growth, the growth in industrial production etc., in an equation like (2.6). They reported the p-values for the F-tests associated with the added macro variables. They also estimate the standard errors of the forecasts. Samanta (1999) employed the marginal forecasting criterion for India using equation similar to Bryan and Cecchetti (1993). He estimated regression of measured inflation rate on past values of annual growth in various forms of inflation measures as well as for exclusion-based core measures. He included other macro variables such as annual growth in money supply (M3), IIP and the exchange rate in regression models taking lags via 'stepwise regression' up to 12 months. However, many researchers have concluded that there is little improvement by using multivariate instead of univariate model to gauge forecasting ability of core inflation.

2.4.2.4 Relationship between Inflation Measures and Monetary Variables

The pioneering LIE method of Bryan and Cecchetti (1993) was primarily motivated to find a core inflation measure that highly correlated with money growth. They evaluated their measures of core inflation by using basic propositions from monetary theory - core inflation should be caused by, but should not cause money growth. This relationship was

evaluated employing simple regression model and a series of Granger-style tests. Their estimated simple regression is similar to:

$$\pi_{t+h} = a + \sum_{i=1}^k \beta_i M_{t-i} + \varepsilon_{t+h} \quad (2.14)$$

where π_t are the alternative inflation measures in period t , h is forecast horizon and M is the money supply growth rates while the number of lags (k) can be set using information criteria. Bryan and Cecchetti applied Granger type tests using single equation specification like equation (2.8), where π_t^* here should be taken to be the money supply growth and π_t to be seen as one of the core inflation indicators. For assessing such relationship, Samanta (1998) has used standard ‘VAR model’ to conduct Granger’s causality tests for WPI inflation as well as various core measures separately for India.

Bilke and Stracca (2007) suggested that a measure of core inflation should be assessed by its relationship with monetary policy decisions instead of examining its ability to track trend inflation and forecasting performance. They argue that “if a certain core inflation measure captures impending and sustained swings to inflationary pressures and the central bank reacts to such pressures, then the core inflation indicator will be correlated with the monetary policy instrument, rather than with future headline inflation”(p. 1034). They estimated a simple Taylor-type policy rule to examine relation between different indicators of core inflation and the ECB (European Central Bank) monetary policy stance. Their estimated Taylor- type policy rule regression had the following form:

$$r_t = \alpha + \beta y_{t-2} + \gamma \pi_{t-2}^* + \varepsilon_t \quad (2.15)$$

where r_t is the ECB main refinancing rate used as proxy for the ECB monetary policy stance, y_t is industrial production detrended with the Hodrick-AR Prescott filters at monthly frequency and was taken as an indicator of economic slack in the economy and π_t^* is one of the core inflation indicators. Bilke and Stracca argue that ECB takes monetary policy decisions at the beginning of each month, therefore in order to have realistic information set available at the decision time t , they includes a two month lag of each explanatory variable. They interpret a positive and significant ' γ ' as an indication

that the core inflation measure includes information that is relevant for monetary policy decision.

Other studies such as Vargas *et al* (2009) suggest that core inflation should exhibit a close relationship with macroeconomic determinants of inflation, specifically with lagged values of the output gap and the change in the price of imports. To check for this property, they performed causality tests between output gap and core inflation by estimating open economy Phillips curves for Colombia. They also checked in-sample and out-of-sample fit of estimated Phillips curves.

2.5 Concluding Remarks

Despite widespread use of core inflation in the conduct of monetary policy, there is neither an agreed definition nor an agreed method of measuring it. This is partly because there is no theoretical framework of measuring core inflation like cost of living index which is based on micro-economic foundations of welfare optimization (theory of utility). As a result, a wide variety of alternative approaches have been proposed for measurement of core inflation. All these approaches have relative advantages and disadvantages and none of them have emerged as a clear winner over the rest so far. Notwithstanding this, statistical measures of core inflation have some clear advantages over the multivariate model based core measures. Model based core measure has a number of imitations though it has some basis in theory. One important limitation is that its history changes each time new data is added. This is also true for DFI model. This feature limits use of these measures as indicators of core inflation.

Among statistical measures of core inflation, a large number of central banks have been publishing conventional ex-food and energy type measures and LIE based trimmed means as well. Given simplicity in computing and being readily understandable to public, most central banks monitor exclusion based core measures especially such measures are used as communication measures. However, recent demand shock to oil prices and persistency in commodity prices suggests that exclusion should be judged based not only on its historical volatility and economic rationale but also on the existence of such volatility in future. its source of volatility should also be checked as new data arrive. On the other hand, the

proponents of LIE have argued for both statistical and economic rationale. Its statistical terms, supported by evidence on non-normality in price distribution at different time and across-country, they have argued that LIE is the best estimator of central tendency in class of estimators such as simple weighted mean. As a result, a large number of central banks are computing trimmed means and tend to use such measures both in internal policy decision and for external communication.

Given lack of an agreed upon single core inflation measure, different statistical criteria have been applied in order to judge the best measure among alternatives. Indeed, the various empirical criteria by which measures of core inflation are evaluated are implicitly linked to uses of core inflation in monetary policy. Hence, reviews of various empirical criteria of core inflation were carried out by linking these criteria in a common conceptual framework. So, we explored the gap tests model in some detail and UAE tests, and tracking trend inflation criteria and forecasting models. However, there are some arguments questioning whether forecasting criterion should be used as a sole yardstick to judge a useful core measure. This criterion was suggested by Blinder (1997) and Freeman (1997) and has widely been implemented in the literature. Marques *et al* (2003) questioned use of forecasting criterion to judge a useful core measures. But given the central bank interest in medium term inflationary outlook, forecasting criterion is also a useful criterion vis-à-vis other empirical criteria of core inflation to assess a useful core measures among alternative inflation measures.

CHAPTER 3

MEASURING CORE INFLATION IN INDIA: AN ASYMMETRIC TRIMMED MEAN APPROACH

3.1 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 skewed¹⁵, 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 skewness 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 chapter 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

¹⁵ 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.

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 chapter is organized as follows: Section 3.2 discusses limited influence estimator (LIE) approach as a core inflation measure. Section 3.3 describes key characteristics of cross-sectional distribution of price changes in India. Section 3.4 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.

3.2 Limited Influence Estimator

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 inflation¹⁶. 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. For detail discussion on theoretical argument of LIE and statistical theory of symmetric versus asymmetric trimmed mean refer section 2.3.2.1.1 and 2.3.2.1.2 respectively in previous chapter 2.

¹⁶ Measured inflation, headline inflation and WPI inflation are used here as interchangeable terms.

3.3 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 shortcomings 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:

$$P_t = \sum_{i=1}^n w_{i0} P_{it} \quad (3.1)$$

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:

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

$$\text{Thus, } \pi_t = \sum_{i=1}^n w_{it} \pi_{it} \quad (3.2)$$

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:

$$m_{kt} = \sum_{i=1}^n w_{it} (\pi_{it} - \pi_t)^k \quad (3.3)$$

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

$$S_t = m_{3t} / (m_{2t})^{3/2} \quad (3.4)$$

$$K_t = \left\{ m_{4t} / (m_{2t})^2 \right\} - 3 \quad (3.5)$$

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 3.1 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 skewness 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.

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 ($\equiv 50^{\text{th}}$ 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 50^{th} 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 50^{th} percentile. Figure 3.2 plots empirical mean percentile for the price change distribution over the sample period. The result suggests that the mean percentiles lie above 50^{th} 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 3.2 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 dotted line in the Figure. This indicates that the sample means of price change distribution, on average are contained at 58^{th} percentile.

Finally, Figure 3.3 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.

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.

3.4 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.

3.4.1 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 3.1 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 skewness (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 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 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 50th 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. Likewise, when $c=57$, we have $TM(57, 15)$ which 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.

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 $c = 50$. 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.

3.4.2 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 measures. 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 3.1 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:

$$\pi_t = a_0 + \beta_1 \pi_t^* + u_t \quad (3.6)$$

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 3.2 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 $\Delta\pi_t$,

$$\Delta\pi_t = \sum_{j=1}^m a_j \Delta\pi_{t-j} + \sum_{j=1}^n \beta_j \Delta\pi_{t-j}^* - \gamma(\pi_{t-1} - \pi_{t-1}^*) + \varepsilon_t \quad (3.7)$$

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 3.3 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^* :

$$\Delta\pi_t^* = \sum_{j=1}^r \delta_j \Delta\pi_{t-j}^* + \sum_{j=1}^s \theta_j \Delta\pi_{t-j} - \lambda(\pi_{t-1}^* - \pi_{t-1}) + \eta_t \quad (3.8)$$

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 here use Schwarz Information Criterion (SIC) to set the number of lags.

Third column of table 3.4 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 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 ($\lambda = \theta_1 = \dots = \theta_s = 0$) in equation (8) in the fourth column of table 3.4 shows that among the 18 asymmetric trimmed means (that passed the weak exogeneity test ($\lambda = 0$)), 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 3.4).

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 3.5 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 3.4 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 3.6. Relative 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.

3.4.3 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 3.5 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 test¹⁷.

3.5 Conclusion

This chapter applied the asymmetric trimmed mean approach to measuring core inflation in India. It 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 a class of the trimmed means measures. For this purpose, the chapter 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 Chapter 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 chapter 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.

¹⁷ This is also true for any trimmed mean that put relatively more weight on right hand tail distribution.

Table 3.2: Test 1-Unbiased Property of Core Inflation

Trimmed mean	p-value of F-test	Trimmed mean	p-value of F-test	Trimmed mean	p-value of F-test
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*

Cont...

Cont...

Trimmed mean	p-value of F-test	Trimmed mean	p-value of F-test	Trimmed mean	p-value of F-test
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.

* indicate test of unbiasedness is satisfied

Table 3.3: 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	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 3.4: Test 3- Exogenous Property of Core Inflation

	Test 2: Attractor Property of Core Inflation	Test 3: Exogenous Property of Core Inflation (a)	Test 3: Exogenous Property of Core Inflation (b)
Trimmed means	p -value, $\gamma = 0$	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

* indicate test of weak exogenous is satisfied

** indicate test of strong exogenous is satisfied

Table 3.5: Test 3 - Exogenous Property of Core Inflation

Estimation Sample: 1999m04 2008m04

	Weak Exogeneity <i>p</i>-value, $\lambda = 0$	Strong Exogeneity <i>p</i>-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

* indicate test of weak exogenous is satisfied

** indicate test of strong exogenous is satisfied

Table 3.6: 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

Table 3.1: 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

Figure 3.1

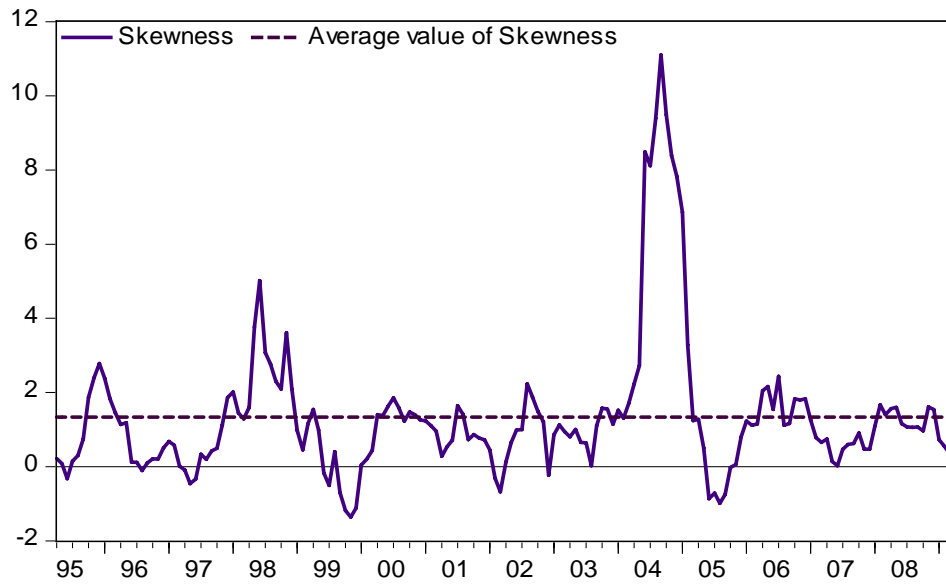


Figure 3.2

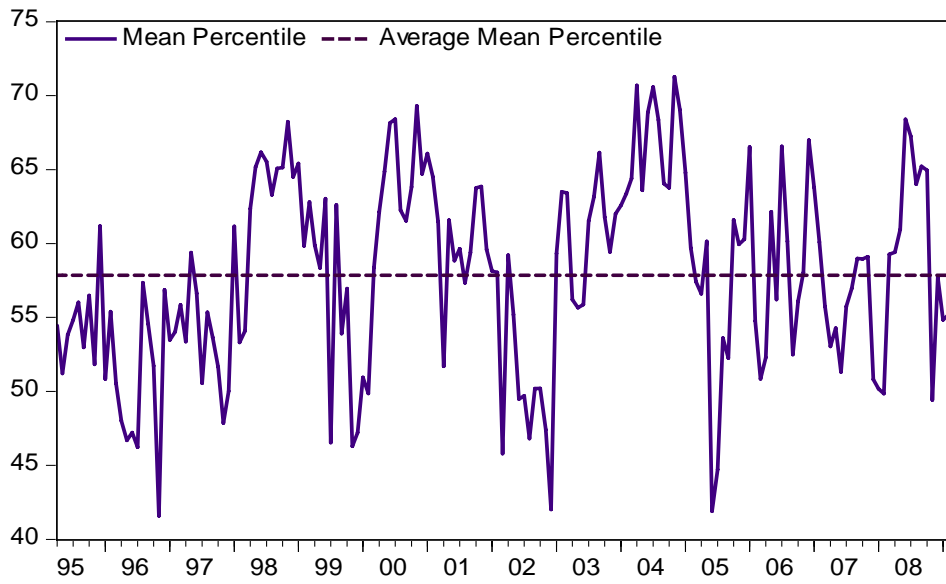


Figure 3.3

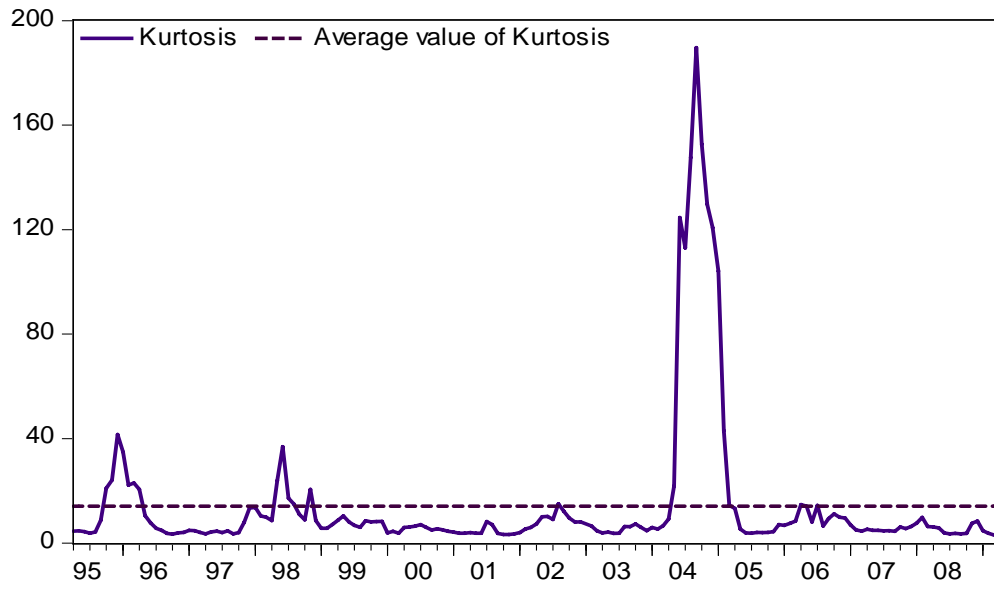


Figure 3.4: Asymmetric Trimmed Means

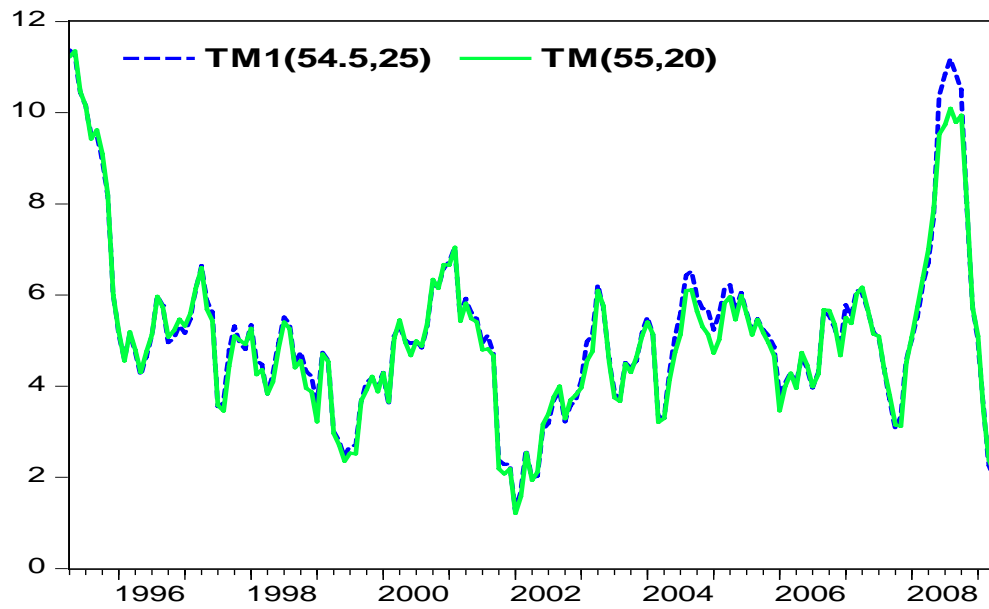
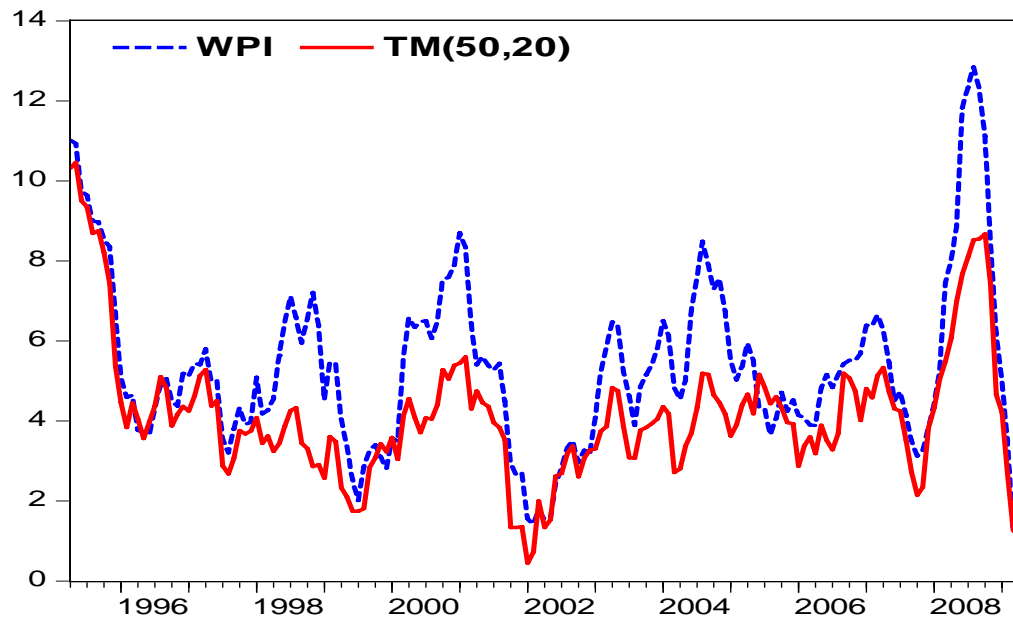


Figure 3.5: Symmetric Trimmed Mean and WPI Inflation



CHAPTER 4

AN ESTIMATION AND COMPARISON OF STATISTICAL MEASURES OF CORE INFLATION FOR INDIA

4.1 Introduction

The chapter-2 has discussed various alternatives methods of measuring core inflation under two broad categories: modeling approach and statistical approach. The present chapter computes measures of core inflation associated with the statistical approach. This is mainly because the existing literature argues in favour of statistical approach in view of its relative simplicity and statistical robustness to measuring core inflation. Consequently, such measures of core inflation are most frequently used by central banks and the market participants are more familiar with them.

In previous chapter, an attempt was made to find best trimmed mean-core inflation measure for India in the class of the trimmed mean measures. In this chapter an attempt is made to take the rest of the task, constructing other alternative measures of core inflation, and subsequently assessing their empirical performance basis on empirical criteria of core inflation outlined in the chapter 2.

The remaining chapter consists of four sections with the following structure. Some empirical evidence from existing studies on performance of alternative core inflation measures is provided in section 4.2. Section 4.3 provides details on constructing and implementation of different statistical core measures in India. The derived inflation measures are compared using various empirical criteria of core inflation in the section 4.4 and section 4.5 provides a summary of findings.

4.2 Core Inflation Measures: A Review of Empirical Evidence

In this section an attempt is made to review findings of some important studies, most of which either propose a new core measure or evaluating criteria or assess performance of

existing measures. The literature covered is not exhaustive but representative of major contributions in core inflation literature.

An empirical assessment of alternative measures of core inflation was first provided in Bryan and Cecchetti (1993). They first calculated trimmed mean-15 and weighted-median core inflation and also conventional Ex-food-energy strategy to U.S data from Feb-1967 to Dec-1992 using 36 components in headline CPI. To test the superiority among three core measures, they then examined the relationship between money and inflation by employing a series of Granger tests. Further, using a univariate model they tried to test the forecasting ability of each core measure to headline inflation (CPI) over one to five years. For examining the marginal forecasting power of core inflation, the univariate model was extended into multivariate framework with other macro variables namely, money, output and nominal interest rate. The study showed that among the three alternative core measures the weighted-median was superior in terms of its relationship with money growth and ability to forecast future inflation. Using 54 components of the CPI index, Laflèche (1997) developed a number of core inflation measures based on statistical methods for Canada. He then employed a simple regression model in order to determine ability of the different measures of core inflation in forecasting the future path of CPI inflation, and found that double weighed core inflation measure (CPIW) and CPI excluding indirect tax (CPIX) appeared to contain the most information on the future path of the CPI inflation.

Roger (1998) provided an overview of issues relating to conceptualization and relevance of core inflation for monetary policy formulation and accountability. He examined various empirical approaches to measuring core inflation and argued in favour of the LIE method. He also argued favorable for LIE method being suitable in the developing country context in terms of its relative robustness to measurement error and also it's speed of adjustment to relative price shocks.

Marques *et al* (2000) proposed three necessary testable conditions of core inflation and evaluated 8 core inflation measures against their proposed three tests for the Portuguese case. The evaluated three core measures are : central moving average (37,25,13 months), the 10 % and 25% symmetric trimmed mean, ex-food and energy, core measure of first

principal component and the standard deviation weighted core inflation measure. They found that only core measure of first principal component, standard deviation weighted core inflation measure and 37- month central moving average were able to meet all the three criteria of core inflation. They concluded that using moving average series as reference measure in evaluating trend property of core inflation can be misleading. They also showed why ex-food and energy type core measures can not be expected to meet three theoretical criteria of core inflation by proposed by them.

Clark (2001) examined five core inflation measures for U.S based on two basic methods: exclusion and limited influence estimator. These five core indices are: (a) CPI ex-food and energy; (b) CPI ex-energy; (c) CPI ex-8component; (d) trimmed mean; and (e) median CPI. He used two criteria to evaluate performance of alternative core measures, namely: ability to tracking trend inflation and forecasting ability using Gap test model. The study concluded that the trimmed mean and CPI ex-energy are superior core measures. Similar study was conducted by Vega and Wynne (2001) for the Euro area. They examine two measures of core inflation using limited-influence estimator method and neo-Edgeworthian or variance-weighted price index, and compare these measures with conventional exclusion based core measures in the Euro area. The main focus of the study was to see whether the limited-influence or Edgeworth measures of core inflation can deliver better performance than the traditional exclusion based measures on the basis of two criteria i.e., their ability to track movements in trend inflation; and ability to predict future headline inflation. On the basis of empirical evidence, the study concluded that, in terms of tracking trend inflation and forecasting future headline inflation, trimmed-mean measures of core inflation are a useful input to the monetary policy process. Smith (2004) in her paper defined core inflation as a best forecaster of inflation. Around this definition, she studied several core inflation measures including weighted median, trimmed mean, ex-food-energy and also lagged headline inflation in order to determine which one is the best predictor of future headline inflation. The goal of the study was to find a best forecaster of inflation in the new monetary regime of U.S. He employed different time-series models for both in-sample and out-of-sample forecasting for PCE and CPI over data period from 1982:1 to 2000:12. The study used bias adjusted

series in the forecasting model. The results showed the weighted median as a best forecaster of future inflation.

Cutler (2001) first computed persistence weighted core measures with weight derived from first-order auto regressive model (AR-1) using monthly data at disaggregate level for period 1976 to 2000 for UK. Superiority of persistence weighted core measure was then examined against then other existing seven core measures in U.K on the criteria of ability to predict future inflation using Gap model. Cutler found the persistence weighted index ranked third after core measure RPIY and core measure ex-food-energy-duties over a number of in sample forecasting horizons. Bike and Stracca (2007) also applied persistent weighted core measure in the Euro area. They computed three persistence weighted core measures taking three different criteria to measuring persistence weights viz., the sum of auto regressive coefficients, the mean reversion and correlation with future headline inflation. Bike and Stracca (2007) assessed the performance of three persistence weighted core measures against other existing core measures basis on Taylor-type Policy Rule model. Their study found that only persistence weighted core measure shows significant relation with ECB (European central bank) main refinancing rate.

Cogley (2002) proposed a new core measure, 'exponential smoothed core measure'. He then applied 'gap' test model to assess the predictive ability of his new measure vis-à-vis other ex-food and energy, trimmed mean and weighted median and smoothing latter three series over the quarterly data from 1967 to 1997. He further investigated marginal predictive power of each core measure by using multivariate version of 'gap' model along with other macro variables and found that his new core measure alone resulted in increased R-squared. Rich and Steindel (2005), evaluating several alternative important core measures against each other within a common testing framework, point out that there is lack of uniformity. They examine alternative core measures based on both the US CPI and PCE inflation for period from 1959 to 2003 and apply a common set of statistical criteria: (1) the ability to track the trend rate of inflation using RMSE criterion and match

the long-run average rate of inflation, (2) forecasting ability within-sample movements in inflation, and out of sample forecast using both univariate and multivariate version of Gap test model. They also make several robustness checks, including varying the forecast horizon and sample period. Among the alternatives core measures they consider are ex food and energy, ex energy, median, and Cogley's exponentially smoothed inflation. The result of their study revealed that: (1) almost all individual core measures demonstrated the ability to tracking the means inflation of inflation. (2) within sample, median measure and its smoothed version had substantial predictive power for changes in inflation several years in advance. (3) in the out of sample forecasting however, no measure performed well. They, therefore, conclude that no individual core measure is unambiguously superior to others.

4.2.1 Studies on Core Inflation Research in India

A small number of studies have so far attempted to measure core inflation for India. Among these, Samanta (1999) first made an attempt to construct four conventional ex-food and fuel type core measures. He excluded a large set of administrative and other commodities whose weight was around 50 percent in WPI. He tests these four core measures by employing the following criteria, forecasting power of core measure to headline inflation and causal relationship between money growth and core inflation. Mohanty *et al* (2000) computed core inflation measures using symmetric trimmed mean estimators and exclusion principle using data on WPI prices with 1981-82 base year. They tested for cointegration and Granger causality between money supply and alternative measures through a trivariate VAR model which also included IIP. Based on the overall result, they proposed WPI-20 % trimmed core measure for the purpose of monetary policy in India. However, the study calculated only three symmetric trimmed mean and further, given skewness in price change distribution in India, the symmetric trimmed means are bound to be biased estimators of headline inflation. Mohanty *et al* (2000) measures were implemented in Joshi and Rajpathak (2004) for the sample period April-1983 to March-2003 using two different base prices. Joshi and Rajpathak (2004) calculated five exclusion type measures and three symmetric trimmed mean measures. They compared these measures by using criteria such as basic statistics and co-integration test and Granger causality test, though they found all inflation measures are I (1). Das *et al* (2009)

calculated 12 different core measures utilizing existing statistical methods and SVAR model. They reported graphs on these different core measures along with WPI inflation for the sample period Jan-2000 to Dec-2007, which show the graph on core measures: the Mean-SD, Median and 16 % percent symmetric trimmed mean clearly indicate that these measures lie distant below the WPI inflation rate, showing a systematically downward bias of these measures with respect to WPI inflation. The study neither provided/mentioned aggregation of commodities indices used nor methodology for computation of these measures. Kar (2009) evaluated statistical based core measures and geometric exponential smoothing measures. The study examined the proposed core measures against the benchmark 36-month centered moving average using volatility and forecasting criteria. Based on the results, the study concludes that the 57th percentile and exponential smoothing core measure can be useful indicators of core inflation in India.

Two papers namely, Goyal and Pujari (2005) and Durai and Ramachandran (2007) are chiefly related to the application of SVAR based core measures in India. The former study implemented Quah and Vahey (1995) two variable SVAR model in deriving core inflation in India. While, the later study used multivariate common trend model, which was proposed by Baglino and Morana (2003), to derive core inflation through multivariate VAR model which included WPI inflation, growth in M3 and log of oil prices using monthly data for the period April 1994 to March 2005. Durai and Ramachandran (2007) evaluated core measure based on common trend model against conventional ex-food and fuel core measures and, 15% and 20% trimmed mean measures using basic statistics and predictive property of core inflation in the VAR framework. On the basis of empirical results, they suggested that core measure of common trend model is a good indicator of future inflation for internal decision of monetary policy in India.

Having presented the existing research on core inflation in India, the present chapter constructs several statistical based core measures for India and provides their methodology on the construction of core measures, and subsequently it provides a comparison of those core measures in a systematic testing framework.

4.3 Alternative Statistical Measures of Core Inflation for India

Data and Other Descriptions

The dataset is composed of monthly 69 individual price indices of Wholesale Price Index (WPI) and covers the period, April 1994 to April 2009, with 1993-94 as the base year. We note as of now RBI bases its definition of price stability in terms of WPI. We calculate and evaluate all measures of core inflation on the basis of year on year inflation. The yoy inflation is a general and standard measure followed at central banks world wide. RBI also expresses its inflation target in terms of year on year price change in WPI index. Moreover, yoy inflation partially corrects the seasonality present in the WPI index.

Before constructing statistical measures of core inflation, it is advisable to check some basic descriptive statistics of the WPI data. We calculate descriptive statistics for cross-sectional distribution of yoy change in prices of commodity groups (69 components) for a given month. Thus every month provides values for mean standard deviation, skewness, kurtosis and mean percentile. The first row of table 4.1 gives mean of these values respectively and second row gives median of these values respectively over all the months included in the study. Thus, the first column gives mean of yoy price changes for given month, which nothing but WPI inflation rate and mean of this WPI inflation rate over study period is 5.37 %. Table shows that the mean value of standard deviation of price change distribution is quite large relative to the WPI, indicating that there is considerable noise in the WPI data. Further, results indicate, as noted in previous chapter, that the distributions of price changes are not normal, i.e. leptokurtic and skewed to the right. The mean values for coefficient of skewness and kurtosis are 1.34 and 14.18 respectively which are larger than corresponding normal distribution. The headline inflation rate accommodates different type of non-monetary idiosyncratic shocks which are not related to underlying trend inflation. The statistical measures of core inflation are response to these problems.

Calculating Alternative Statistical Measures of Core Inflation for India

In subsequent sections, an attempt is made to calculate a number of core inflation measures for India based on different statistical methods. They all take an existing price index and then either remove certain volatile items from it on an economic/statistical basis (exclusion principle), or systematically (LIE -trimmed mean and median measures,), or re-

weight the components of that index depending either on its variability or persistence (volatile or less persistence items are down weighted and stable components are given relatively higher weights) or by using trend methods to extract the ‘underlying’ trend components inflation from measured inflation (moving averages/ smoothing/filter technique).

4.3.1 Exclusion Based Core Inflation Measures:

A). Permanent Exclusion: Subjective Approach¹⁸

The first task for computing core measures, that use exclusion principle, is to identify components in headline index that are to be excluded. One standard ad hoc approach is to exclude those components that show heavy supply shock characteristic and whose prices are not easily controllable by central banks. On this consideration, a wide variety of components from headline index at cross-country level are candidates for exclusion. Further, some researchers believe that, in general, monetary policy should ultimately focus on broadest price index possible. With that in mind and taking into account that RBI has also started began publishing ex-food & fuel type measures, we construct the following exclusion core inflation measures:

- 1) WPIEXPA: obtained by excluding primary food article (with a weight of 22.02 percent) from WPI index.
- 2) WPIEXFD: obtained by excluding food (with a weight of 15.4 percent) from WPI index.
- 3) WPIEXFD&FL: obtained by excluding food (with a weight of 15.4 percent) and fuel categories (with a weight of 14.2 percent) from WPI index.
- 4) WPIEXFL: computed by excluding the fuel category (with a weight of 14.2 percent) from WPI index.

B). Permanent Exclusion: Objective Approach

¹⁸ RBI reports such exclusion type measures under ‘Price Situation’ section in its macro-monetary development report.

We also identify exclusion components based on to be ‘objective approach of exclusion’ wherein components are excluded on the basis of their volatility either over the time or on a cross-section basis. The detailed analysis of volatility statistics of each of the components series are reported in Table 4.2.

First, we identified the components that are frequently found to be in the tails of the cross-sectional distribution of price changes. To be more specific, components for exclusion are those whose year on year (yoy) inflation falls out side the given ‘interval’ of cross sectional distribution of price changes at least $\alpha\%$ times, the given interval is defined as $\pi_t \pm \rho_t$, where π is WPI inflation, and ρ_t is weighted standard deviation of the price distribution in month t ,

$$\rho_t = \sqrt{\sum_i^n w_{it} (\pi_{it} - \pi_t)^2} \quad (4.1)$$

We consider two values for $\alpha\%$, namely 25% & 20% to construct two such core measures,

1) WPIEX25%¹⁹ : computed by excluding components whose year on year inflation have fallen at least 25% times out of interval defined by $\pi_t \pm 1.5 \rho_t$. The excluded component (with a weights of 10.47) series are: Vegetables, Condiments & Spices, Other Food Articles, Fibres, Metallic Minerals, Manufacture of Common Salts, Edible Oils, Oil Cakes, Tea & Coffee Processing, Jute Hemp & Mesta Textiles and Basic Heavy Organic Chemical

2) WPIEX20% : computed by excluding components whose year on year inflation have fallen at least 20% times out of interval defined by $\pi_t \pm 1.5 \rho_t$. This core measure additionally excludes 4 series thus total 15 series (with total weights of 19.13). The four additional series are: Pulses, Fruits, Oil Seeds and Sugar, Khandsari & Gur.

We also construct core index on the basis of historical volatility. The core index-WPIEXMost15, which excludes fifteen of most volatile components from WPI as these

¹⁹ The Bank of Canada publishes regularly such type of core inflation measure in the Bank of Canada Review.

fifteen series are historically most volatile among 69 components series of WPI. The volatility is measured by standard deviation (S.D) of y-o-y inflation of each component over the sample period.

3) WPIEXMost15: computed by excluding (with a weight of 17.22%) fifteen series: Vegetables, Condiments & Spices, Other Food Articles, Fibres, Metallic Minerals, Minerals Oils (Petrol & Petroleum Products) Preserving & Processing of fish, Manufacture of Common Salts, Edible Oils, Oil Cakes, Tea & Coffee Processing, Jute Hemp & Mesta Textiles, Wood & Wood Products, Printing & Publishing Of Newspapers, Periodicals, Basic Heavy Organic Chemical.

Note that most of the excluded series from the above core measures are also appealing to economic rationale for example prices of Vegetables, Fruits, Pulses, tea & coffee, Oil Seeds edible oils, petrol & petroleum products, Sugar, Khandsari & Gur and basic heavy organic chemical etc are mostly either driven by supply shocks or affected by world prices or government policy²⁰.

The difference between WPIEXFD&FL measure (combined weight 29.6%) and WPIEXMost15 (combined weight 17.22%) is that latter core index does not exclude whole food and fuel components series rather it excludes only 4 components (weight 9.34) from food & fuel category and remaining 11 out of 15 components excluded from outside the food and fuel baskets.

With respect to fuel category, the major difference between WPIEXMost15 and WPIEXFL is that the former core measure exclude only mineral oil group (6.99%) whereas the later conventional measure exclude all fuel category (14.2%)²¹.

²⁰ We also analyzed standard deviation of monthly inflation of seasonally adjusted 69 individual series. From the table 4.2, one can see the most volatile components are the same to ones that excluded from the above core indexes.

²¹ However, note that WPIEX25% and WPIEX20% core indexes do not even exclude Mineral Oil ((Petrol & Petroleum Products) components. This suggests that basis on a cross-sectional volatility criterion, Minerals Oil component show stable component, bringing a signal and suggest Minerals Oil component should not be removed. Indeed, Minerals Oil is an administrative component and it is also affected by world prices. So considering these, it is advisable to take account the source of volatility and its existence in near future when calculating core prices from WPI prices. In next section, we compute core inflation measures basis on month by month exclusion criterion, which can be useful in this regard.

The idea behind objective approach of exclusion is that the whole food and fuel categories may not be among the most volatile component indeed only some of them may most volatile and the remaining part of them may show persistence. Therefore, excluding whole fuel and/or food categories mean excluding an important signal of the underlying trend of inflation rate. This can be seen in table 4.3 that show the conventional ex-food and fuel core measures are more volatile than headline inflation and core inflation measures based on the objective approach of exclusion. Further, the table shows that the p-value of wald test (unbiasedness test)²² for WPIEX25% and WPIEX20% are statistically insignificant, suggesting that these measures are unbiased estimator of WPI inflation.

Construction of exclusion based core inflation measures:

To start with consider the well-known definition of Laspeyres price index, which is base year weighted price index. Let there be n commodities. Subscripts “t” denotes particular time ‘t’, t=0, it represents value of the concerned variable in the base period, chosen for constructing the price index. Then, Laspeyres price index P_t is given as:

$$P_t = \frac{\sum_{i=1}^n q_{i0} P_{it}}{\sum_{i=1}^n q_{i0} P_{i0}} \times 100$$

(4.2)

Taking $w_i = \frac{q_{i0} P_{i0}}{\sum_{i=1}^n q_{i0} P_{i0}}$

$$P_t = \sum_{i=1}^n w_i \frac{P_{it}}{P_{i0}} \times 100$$

²² For this test refer regression equation (3.6) in chapter-3

Now, exclusion core measure is defined on the basis of prices of a subset of the aggregate index basket. Suppose goods within the aggregate index basket are ordered in such a way that the core price level includes goods 1 to m , and fully excludes goods $m+1$ to n . Then,

$$P_t^{core} = \frac{\sum_{i=1}^m w_i \frac{P_{it}}{P_{i0}} \times 100}{\sum_{i=1}^m w_i} \left(\frac{\sum_{i=1}^m q_{i0} P_{it}}{\sum_{i=1}^m q_{i0} P_{i0}} \times 100 \right) \quad (4.3)$$

Where $m \leq n$

The denominator rescales the weights for commodities 1 to m and commodities $m+1$ to n are re-assigned to have weights zero. The 12-month change in this index (4.3) gives exclusion based weighted year-on-year core inflation rate.

4.3.2 Limited Influence Estimator Based Core Measures

A) Asymmetric Trimmed Means²³

Following the conclusion of section 3.5 in the previous chapter, we here take TM (55.4, 25) and also TM (55, 20) trimmed means series to compare them vis-à-vis other statistical core measures. It is pertinent to recall that these asymmetric trimmed means are best measures in the class of the trimmed mean measures. TM (54.4, 25) is 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.

B) Median and 58th Percentile Core Measure

Bryan and Cecchetti (1994) have suggested the median as another useful core inflation measure.

1) Median: The median inflation rate is simply equal to a price change items correspond to a 50th percentile, which is the median of the ordered year on year price changes in the data.

²³ For computation of these measures, see section 3.4, in chapter 3.

As discussed in chapter-2, section 2.3.2, the median is a special case of symmetric mean and given right skewed price change distribution in India, the median is bound to be systemically biased estimator of headline inflation rate. Nevertheless, it is empirically found a good forecaster of headline inflation, for instant see Bryan and Cecchetti (1993), Smith (2004).²⁴

2) 58th Percentile core measure: this is price changes correspond to an average mean percentile-58th; it is simply obtained as year on year inflation rate of the component that corresponds to a 58th percentile²⁵.

The percentile core measure was proposed by Roger (1997). The percentile core inflation measure is also interpreted as adjusted median core measure i.e., core inflation rate corresponding to average mean percentile instead of 50th percentile as in the above simple median case.

C) Month by Month Exclusion-Core Inflation Measures (dynamic trimmed mean)

This core measure excludes components on the basis of its contribution of weighted inflation volatility in the distribution of cross-sectional prices changes in each month. It excludes components on month by month basis whose year on year inflation falls outside the defined *interval* of the cross-sectional distribution of price change of all the components. We defined five threshold *intervals* as $\pi_t \pm 0.5 \rho_t$, $\pi_t \pm \rho_t$, $\pi_t \pm 1.5 \rho_t$, $\pi_t \pm 2 \rho_t$, $\pi_t \pm 2.5 \rho_t$ of the distribution of the yoy price change of all the components, π represent WPI inflation and ρ for weighted standard deviation of the price change distribution in a given month. The items whose inflation falls out of the respective interval (distribution) are given zero weight and remaining components are rescaled with the time varying original weight so that they still sum to one²⁶. Five core inflation indicators have been named as it follows:

²⁴ The bias in the core measures are discussed in the evaluation section 4.4.3.

²⁵ In the previous chapter, the average mean percentile was found around 58th percentile in India.

²⁶ Month by month exclusion-based core measures are simply dynamic form of trimmed mean, where percentage of excluded commodities (trimming percentage/ratio) changes for each month.

- 1) WPIMBM5 is computed excluding components whose y-o-y inflation fell outside interval $\pi_t \pm 0.5 \rho_t$
- 2) WPIMBM10 is computed excluding components whose y-o-y inflation fell outside interval $\pi_t \pm \rho_t$
- 3) WPIMBM15 is computed excluding components whose y-o-y inflation fell outside interval $\pi_t \pm 1.5 \rho_t$
- 4) WPIMBM20 is computed excluding components whose y-o-y inflation fell outside interval $\pi_t \pm 2 \rho_t$
- 5) WPIMBM25 is computed excluding components whose y-o-y inflation fell outside interval $\pi_t \pm 2.5 \rho_t$

Core measures based on the permanent exclusion are not always useful in identifying and providing information on source of volatility in each month as it excludes certain components once for all. According to Blinder (1997) “The name of the game was distinguishing the signal from the noise, which was often difficult. What part of each monthly observation on inflation is durable and which part is fleeting?” (p. 157). The RBI analyses the sectoral inflation development and its impact on overall inflation development in its quarterly report on ‘price section’, in view of short term sectoral inflation development is primarily driven by the dynamics of the sectoral specific market. In this regard, the month by month based core inflation measures are useful for identifying and analyzing the source of noise in measured inflation development.

4.3.3 Reweighting Core Inflation Measures:

This method of measuring core inflation is based on reweighting of the whole price index at the disaggregated level such that the ‘signal’ or inflationary information in the data is maximized.

(A) Neo-Edgeworthian Core Inflation Measures

Following definition in chapter-2 section 2.3.3.1, variations of ‘Neo-Edgeworthian Index’ are calculated as follow:

- 1) WPISDRP: computed reweighting each 69 components series of WPI by using the weight as the reciprocal of the standard deviation of the change in relative prices, where

the change in the relative price is measured by the difference between inflation rate of each component of WPI and the WPI inflation rate.

2) WPISDS: computed reweighting each 69 components series of WPI by using the weight as the reciprocal of the standard deviation of the inflation rate of each component of WPI

3) WPISDRPDW: double weighted core measure as first suggested by (Laflèche (1997)) computed reweighting each 69 components series of WPI by multiplying the WPI weight by the inverse of the standard deviation of the change in relative prices, where the change in the relative price is measured by the difference between inflation rate of each component of WPI and the WPI inflation rate.

4) WPISDSDW: computed by reweighting each 69 components series of WPI by multiplying the WPI weight by the inverse of the standard deviation of that component inflation rate.

The above four core inflation measures are based on standard deviation of yoy inflation rate of each component. In addition, another four in this class of yoy core inflation measures are calculated, which are based on standard deviation of seasonally adjusted monthly inflation of each component. These four core inflation have been named as: (5) WPISDRPM, (6) WPISDRPDWM, (7) WPISDSM, and (8) WPISDSDWM.

For calculating standard deviation, we have taken all information available for the reference period of the study.

Construction of Reweighted Based Core Inflation Measures:

Following broadly the method shown by Laflèche (1997) and Marques *et al* (2000), we compute four variations of Neo-Edgeworthian index which use both monthly and year on year inflation for calculating standard deviation, thus total eight core inflation index are calculated as described below:

With n price components, the standard deviation weighted year-on-year core inflation measure (WPISDRP) computed as:

$$\text{WPISDRP}_t = \left(\frac{\sum_{i=1}^n W\sigma_i p_{it}}{\sum_{i=1}^n W\sigma_i p_{it-12}} - 1 \right) * 100 \quad (4.4)$$

Where p_{it} standing for price index of i th components of the WPI in period t and $W\sigma_i$ is the weight of i th component defined as the inverse of standard deviation of i th components of WPI. The $W\sigma_i$ are normalized so that they sum to one:

$$W\sigma_i = \frac{\frac{1}{\sigma_i}}{\sum_{i=1}^n \frac{1}{\sigma_i}}$$

Where σ_i is defined as the standard deviation of the change in relative prices:

$$\sigma_i = \sqrt{\left[\left(\frac{1}{T-1} \right) \sum \left[(\pi_{it} - \pi_t) - \overline{(\pi_{it} - \pi_t)} \right]^2 \right]} \quad (4.4b)$$

Where π_{it} represents inflation rate of components i in period t and π_t for the year-on-year inflation rate of WPI in period t .

Year-on-year core inflation measure (WPISDS_t) computed as:

$$\text{WPISDS}_t = \left(\frac{\sum_{i=1}^n W\sigma_i p_{it}}{\sum_{i=1}^n W\sigma_i p_{it-12}} - 1 \right) * 100 \quad (4.5)$$

$$W\sigma_i = \frac{\frac{1}{\sigma_i}}{\sum_{i=1}^n \frac{1}{\sigma_i}}$$

Where σ_i is defined as the standard deviation of i th component inflation rate.

$$\sigma_i = \sqrt{\left[\left(\frac{1}{T-1} \right) \sum (\pi_{it} - \bar{\pi}_{it})^2 \right]} \quad (4.5b)$$

Likewise double weighted year-on-year core inflation measure (WPISDRPDW) computed as:

$$\text{WPISDRPDW}_t = \left[\frac{\sum_{i=1}^n Wd_i p_{it}}{\sum_{i=1}^n Wd_i p_{it-12}} - 1 \right] * 100 \quad (4.6)$$

Where Wd_i is the double weight of the i th component defined as the product of WPI weights (w_i) for the i th component and the inverse of the standard of the i th components $\left(\frac{1}{\sigma_i} \right)$. These weights are normalized so that they sum to one.

$$Wd_i = \left[\frac{\left(w_i * \frac{1}{\sigma_i} \right)}{\left(\sum_{i=1}^n w_i * \frac{1}{\sigma_i} \right)} \right]$$

Where σ_i is defined as the standard deviation of the change in relative prices:

$$\sigma_i = \sqrt{\left[\left(\frac{1}{T-1} \right) \sum \left[(\pi_{it} - \pi_t) - (\bar{\pi}_{it} - \bar{\pi}_t) \right]^2 \right]} \quad (4.6b)$$

Similarly, year-on-year core inflation measure (WPISDSDW_t) computed as:

$$\text{WPISDSDW}_t = \left[\frac{\sum_{i=1}^n Wd_i p_{it}}{\sum_{i=1}^n Wd_i p_{it-12}} - 1 \right] * 100 \quad (4.7)$$

$$Wd_i = \left[\frac{\left(w_i * \frac{1}{\sigma_i} \right)}{\left(\sum_{i=1}^n w_i * \frac{1}{\sigma_i} \right)} \right]$$

Where σ_i is defined as the standard deviation of i th component inflation rate.

$$\sigma_i = \sqrt{\left[\left(\frac{1}{T-1} \right) \sum (\pi_{it} - \bar{\pi}_{it})^2 \right]} \quad (4.7b)$$

Similarly, $WPISDRPM_t$, $WPISDRPDWM_t$, $WPISDSM_t$, and $WPISDSDWM_t$ are calculated using monthly inflation (π_{it}) of each components for calculating (σ_i) in the equations: (4.4b), (4.5b), (4.6b) and (4.7b).

The intuition behind the standard deviation weighted (i.e., $WPISDRP_t$, $WPISDS_t$, $WPISDRPM_t$, $WPISDSM_t$) and double weighted core measures is that former core measures aim is to maximize inflationary signal from data as giving weight as per the components volatility and discard the economic importance of that components whereas the later core measures (double weighted) provides a compromise between the economic significance of a component and inflationary signal it provides by multiplying the WPI weight by the inverse of the standard deviation of that component inflation rate. Double weighted core measures thus augment WPI-related weights with weights inverse relation to volatility. For illustration in Table 4.2, Vegetable, mineral oils and edible oils are seen to be highly volatile therefore has to be excluded or given less weight in core measures, but they have relatively high weight in the WPI basket.

(B) Persistence-Weighted Measures of Core Inflation

Another reweighted measure of core inflation is based on persistence of component inflation rates. We follow Bike and Stracca (2007) sum of AR (p) coefficients model,

instead of Cutler proposed restricted AR (1) model, to derive new weighting scheme for persistence-weighted measures of core inflation²⁷.

To estimate the persistence weights, first the data set of 69 basic price indices are seasonally adjusted using the X12-ARIMA procedures and then monthly inflation rate of the individual components of the WPI are computed. Subsequently, we run the following AR (p) regression for monthly inflation series of each component over the sample period.

$$\pi_{it} = \alpha + \sum_{h=1}^{p_i} \beta_h^i \pi_{i,t-h} + \varepsilon_{it} \quad (4.8)$$

where π_{it} is a monthly inflation rate, in p_i , order of lag for i th component in period t . The maximum number of lags (p_i) in each i th regression is set 12. The order of p_i is chosen so as to minimize the Schwarz information criterion (SC). Then sum of coefficients is obtained simply as:

$$\gamma_i = \sum_{h=1}^{p_i} \beta_h^i \quad (4.9)$$

In computing persistence-weighted core inflation measure (WPIPW), the negative γ_i coefficients are assigned zero weight as in Cutler (2001) and Bike and Stracca (2007) and weight are assigned to other components according to their positive persistence coefficient (γ_i), weights normalized so as to sum to unity. This gives us persistence-weighted year-on-year core inflation measure (WPIPW_{*t*}).

Similar to the above standard deviation double weighted core measures, we also computed double weighted persistence - core inflation measure (WPIPDW) which takes into account of both the persistence of each component series and the original weight of the component in the WPI index.

²⁷ In the inflation literature, there are some other types of persistence measures such as the largest autoregressive root (Cogley and Sargent, 2001) or a non-parametric-the mean reversion persistence measure proposed by Dias and Marques (2005). According to Andrews and Chen (1994), the sum of AR (p) coefficients is the best scalar measure of persistence.

The appendix II reports computed weighting scheme of all the re-weighted core inflation measures.

4.3.4 Univariate –Trend Based Core Inflation Measures:

The trend based methods are used to identify the trend estimate of a measured inflation series. Along this line, Cogley (2002) developed a core inflation measure involving the exponential smoothing of current and past aggregate price changes. We use Cogley (2002) weighted exponential smoothing measure for constructing core inflation measure in India described below:

Cogley’s (2002) formulation can be written:

$$\tilde{\pi}_t = g_0 \sum_{j=0}^{\infty} (1 - g_0)^j \pi_{t-j}$$

Above equation defines the core measure as a one sided geometric distributed lag of current and past inflation, where $\tilde{\pi}_t$ – the period t estimate of mean inflation π – denotes the WPI inflation measure. The gain parameter g_0 is assumed to lie between 0 and 1, and it is the rate at which the updating rule adapts to the mean inflation shift. The process takes approximately $\ln(2)/g_0$, to complete half the adjustment. Cogley (2002) set the gain parameter $g_0 = 0.125$. Note that in constructing the WPES measures, the choice of gain parameter (g_0) need to be made since smaller is the g_0 , the smoother is the series but more backward looking. Considering these, we have estimated the model for different values of g_0 ²⁸ and we here report two exponential core inflation measures (WPIES’s):

- 1) WPIES1: setting parameter $g_0 = 0.125$ (as in Cogley (2002), which take half the adjustment within 5.54 months
- 2) WPIESS2: for parameter $g_0 = 0.105$ which take half the adjustment within 6.6 months

²⁸ We have estimated the model for a large number of different values of g_0 and examined the explanatory power (see equation (4.14), section 4.4.3 below) of the resulting core inflation measure in terms of predictability of future inflation. The results has suggested that the \bar{R}^2 value of equation (4.14) increases with smaller g_0 parameter (i.e., with smother series).

We also estimate HP (14400) filter as trend estimates of headline inflation. However, it should be recalled that the HP filter has the well known end-of-sample problem; it tends to produce distorted estimates of the trend at end points of sample. Hence, the H-P filter can not be always useful core inflation measure in analyzing the current development of underlying trend inflation. Notwithstanding this, unlike other two sided filter, HP trend is available in real time.

The monthly estimates of WPI inflation rate and the estimates of various indicators of core inflation rate are given in the appendix III for the period from 1995:4 to 2009:4. In Figure 4.1 to 4.10, these inflation rates are plotted over the time. When we look at these figures, the movements in various core inflation rates appear to evolve largely similar to the WPI. However, WPIES core measures and HP filter exhibits a smooth graph compared to other core measures.

4.4 Evaluation of Alternative Core Inflation Measures

Similar to alternative measures of core inflation, computed in the preceding sections, there have been a number of empirical criteria for evaluation of core inflation and there is no consensus on the best empirical criteria for ranking core inflation measures. With that in mind, an attempt is made to evaluate various empirical properties of core inflation in the subsequent sections.

4.4.1 Unbiasedness, “Attraction” and Exogeneity (UAE) Test:

As first step, we use Marques *et al* (2000) proposed three criteria for evaluation of core inflation,

Unbiasedness, Attraction and Exogeneity (UAE):

- (i) Core inflation series should be unbiased with respect to the headline inflation
- (ii) Core inflation should be an ‘attractor’ of the headline inflation.
- (iii) Core inflation should be (strongly) exogenous with respect to the headline inflation

Before applying Marques *et al* test, we check unit root test for all inflation series over the sample period April-1995 to April-2009. Table 4.4 shows that the headline inflation as well as all core inflation measures are stationary, I (0). Following Marques *et al* (2000),

the three conditions are then tested for each core measure. Regression equations for these three tests are given in section 3.4.2, chapter-3. The complete results for a range of measures of core inflation are shown in Table 4.5. Results suggest that except asymmetric trimmed means, none of the alternative measures of core inflation pass all the three tests²⁹. The results suggest that the asymmetric trimmed means which were found best asymmetric trimmed means measures in the class of trimmed means measures in the previous chapter are the most useful core measures over the other alternative measures of core inflation according to the UAE tests-criteria. It is here important to note that Marques *et al* tests are although useful criteria but in the literature there are not accepted universally the only or the best criteria to evaluate alternative measures of core inflation. Indeed, the various empirical criteria by which measures of core inflation are evaluated are implicitly linked to uses of core inflation in the process of monetary policy. Considering these, we apply another two standard criteria of core inflation namely, tracking trend inflation and forecasting ability so as to evaluate further the relevance of core inflation measures from the monetary policy point of view.

4.4.2 Tracking Trend Inflation

A good core measure can be evaluated based on its accuracy to track long term trend inflation i.e. over a long period of time, the average rate of core inflation should match the average rate of overall inflation, or be stable and less volatile than headline inflation, or core inflation should move closely with the trend rate of inflation. More specifically, deviation between two series should be minimized. Doing so, we first compute some summary statistics of different core measures. The complete results are reported in the Table 4.6. These show that in terms of comparison of standard deviation, except conventional exclusion type ex-food and fuel core measures and persistence weighted core measures, all other core measures are less volatile than WPI inflation.

²⁹ According to Andrews-Quandt unknown breakpoint test, there is no structural break in the headline inflation data and considering all inflation measures are stationary during the sample period, we can infer that the results are robust with sample changes. Notwithstanding this, the unbiasedness is a condition for a core inflation measure to satisfy over the long run. We therefore, further address this issue in the 'gap' test analysis at different forecasting horizons.

Now, to check core inflation has ability to track trend inflation estimate Root Mean Squared Error (RMSE)/Mean Absolute deviation (MAD) which are given by³⁰

$$RMSE^{Core} = \sqrt{\left\{ \frac{1}{T} \sum (\pi_t^{Trend} - \pi_t^{Core})^2 \right\}} \quad (4.10)$$

$$MAD^{Core} = \frac{1}{T} \sum |\pi_t^{Trend} - \pi_t^{Core}| \quad (4.11)$$

Where π_t^{Trend} is estimate of reference trend inflation of WPI inflation in period t and π_t^{Core} is a particular measure of core inflation in period t .

For reference trend inflation, Bryan and Cecchetti (1997) have suggested using 37-months Central Moving Average of Inflation (CMA37) and it is often used as reference trend series in the literature. Nevertheless, there has been some criticism to this. First, some studies revealed that the results are sensitive to the degree of smoothness of reference trend series. Second, Marques *et al* (2000) argued that the reference trend measure does not guarantee that it is the best proxy for ‘true trend’ of inflation series. The selection of appropriate reference trend inflation is therefore, crucial in assessing the underlying trend inflation property of core measures. To address these issues, we first compute different CMA series and also HP filter³¹. We then select the best reference trend measures by applying the UAE criterion to all the trend measures. The results show that the CMA-37 and HP filter fulfill of the 3 conditions of the UAE (See Table 4.5). So, we use these two series to serve as bench mark-reference estimator of trend inflation in the RMSE trend evaluation process. In Figure 4.10 these two trend series are plotted together with headline inflation. It is here imperative to mention that Marques *et al* (2003) also examined three type of CMA: 13, 25, and 37 months and found that CMA37 fulfills of these three conditions.

³⁰ The MAD put equal penalty for all deviation from the trend series, while the RMSE put a higher penalty on those deviations further from the trend.

³¹ The choice of HP filter as reference trend measure in RMSE approach is motivated through Vega and Wynne (2003). They argue that the assessment of core inflation in terms of detecting changes in trend inflation should be assessed in real time.

To draw some formal statistical inference about which measures of core inflation best tracks long run trend inflation of WPI, in terms of CMA37 and HP filter, we conduct the Diebold-Mariano (1995) test. We construct the Diebold-Mariano (1995) test statistic to test the null hypotheses that two core inflation measures track the trend rate of inflation equally well against the alternative hypothesis that one core inflation measure tracks trend inflation more accurately than the other (Rich and Steindel, (2005)). In the testing procedure, we choose trimmed mean TM (54.5, 25) as the benchmark core inflation series as it shows one of the lowest RMSE value. All the other core inflation series are then compared against the benchmark core inflation series. The Diebold-Mariano (1995) test is computed as follow:

The Diebold-Mariano (1995) test is based on the loss differential. The loss differential is calculated as:

$$d_{t+T} = \left(\hat{e}_{k,t+T}^2 - \hat{e}_{k,t+T}^2 \right) \quad (4.12)$$

where $\hat{e}_{k,t+T}^2 = (\pi_{t+T}^{Trend} - \pi_{k,t+T}^{Core})^2$ and d_{t+T} is the differential loss in period $t+T$ using the benchmark core inflation series ($k = 1$) versus the alternative core inflation series ($k = 2$), while π_{t+T}^{Trend} is correspond to HP filter and CMA37.

The null of equal root mean squared error (RMSE) is then:

$$H_0 : E(d_{t+T}) = 0$$

This is essentially a test of determining whether the mean differential loss (\bar{d}) across a selected sample period (T) is statistically different from 0.

The Diebold-Mariano test statistic is then:

$$S = \frac{\bar{d}}{\sqrt{\hat{V}(\bar{d})}} \quad (4.13)$$

where \bar{d} is the mean of d , and $\hat{V}(\bar{d})$ is the estimated variance. Diebold-Mariano test statistic is constructed using the Newey-West (1987) covariance matrix estimator that allows for heteroskedastic autocorrelated errors.

Starting with RMSE results, Table 4.7 shows that the exponential based core inflation measures are best at tracking both reference - trend of WPI inflation (i.e., CMA-37 and HP-filtered) than all the other core measures. However, it should be noted that the reference trend measures CMA-37 and HP series, and exponential based core measures (WPIES) are filter series, which are derived from the time series data, while all other core measures are calculated from the cross-sectional data at point in time. As a consequence, one can expect WPIES would track its counterpart filter series much better than other core measures. For this obvious reason, we select trimmed mean-core measure (TM (54.5, 25)) as a benchmark series for computing DM test, so that results would be more consistent and interpretable.

With the exclusion of WPIES measures, Table 4.7 shows that in case of CMA-37, RMSE is the lowest for standard deviation double weighted core measure (WPISDSDWM), its RMSE value is 1.12, while corresponding value for TM (54.5, 25) is 1.21, which is the next lowest. However, in terms of MAD metrics, TM (54.5, 25) delivers the lowest value in tracking CMA-37. On the other hand, RMSEs/ MAD's are highest for conventional ex-food and fuel measures and persistence weighted core measures (WPIPW and WPIPDW). This result is clearly related to bias and high volatility which they show in the previous results. In case of tracking HP reference trend series, the results of RMSEs are more or less similar to that of 37-month centre moving average.

Turning to the Diebold-Mariano (DM) test results, it is evident from the Table 4.7 that in case of CMA37, the null of equal RMSE can easily be rejected for conventional ex-food and fuel measures. On the contrary, RMSE for core measures based on objective approaches of exclusion are statistically equal to that of benchmark core measure (i.e., TM (54.5, 25)). Another interesting finding of DM test is that most of the standard deviation weighted core measures particularly standard deviation double weighted core measures are statistically not different from the benchmark core measure. By contrast, persistence weighted core measures are significantly different from the benchmark core measure.

The Diebold-Mariano test results are also similar when HP-trend series is used as reference trend inflation. Only difference is that now all standard deviation weighted core measures are statistically insignificant, indeed its p-values of DM test have greatly

improved compared to that of CMA37. Further, core measures based on month by month exclusion viz., WPIMBM10, WPIMBM15, and 58th percentile core measure which had shown significantly different from bench mark core measure in tracking CMA37 now appeared to be statistically equal to that of bench mark core measure.

Overall results suggest that in terms of relative low volatility and an accuracy of tracking trend inflation, the exponential based core measures, trimmed mean and standard deviation double weighted core measures and WPIEXMost15 do the best job. Indeed, the results of tracking trend inflation are robust to two different reference series, namely CMA37 and HP-trend measure.

4.4.3 Predicting Future Movement in Inflation

This section considers the ability of different core inflation measures to forecast future movement in headline inflation. For further analysis, we however, exclude seven core measures as these measures have shown high volatility and relatively poor performance in tracking trend inflation.

Although there are different ways to judge the predictive ability of a core measure, one common approach is often used in literature by many researchers that if current headline inflation differs from the underlying core inflation rate, headline inflation should move towards core inflation rate. When current overall inflation is below core, overall inflation should rise. To assure this, we follow the ‘gap test’ model that has been used in studies by Clark (2001), Hogan *et al* (2001), Cutler (2001) and Cogley (2002) and Rich and Steindel (2005) etc³².

We estimate the following ‘gap test’ model – the change in overall inflation from today to some point in the future on the current ‘gap’ between core and headline inflation:

$$(\pi_{t+h} - \pi_t) = \alpha_h + \beta_h (\pi_t^{Core} - \pi_t) + \varepsilon_{t+h}, \quad (4.14)$$

where π_t denotes overall headline inflation (WPI) and π_t^{Core} refers to one of the indicators of core inflation, both measured on a year-over-year basis and ε_t is the random

³² The detail discussions on forecasting criteria and for the ‘gap’ model see chapter-2 section 2.4.2.3

error term. The parameter h takes the values of 12, 18 and 24 (months head³³). This ‘gap test’ model captures to what extent transient movements will reverse toward core inflation after shock to headline inflation. If β is less than one, then it understates the transitory movements; if it is greater than one, then it overstates the transitory movements. The coefficient α captures the systematic bias in the measure. Therefore the joint restriction $\alpha=0$ and $\beta=1$ also indicates that core inflation is an unbiased predictor of headline inflation over the h period horizons. Consequently once restriction $\alpha = 0$ and $\beta = 1$ in equation (6) is statistically tested then we can examine information contained in core inflation measures about future movement in headline inflation and this proportion of information, in terms of \bar{R}^2 , can be gauged among alternative core inflation measures.

Within Sample the ‘gap’ Test Model Evaluation:

We now analyze the within-sample results from the Ordinary Least Squares (OLS) estimation of the ‘gap’ model for twenty core measures over three forecast horizons viz., 12, 18 and a 24 months. We use Newey-West corrected standard errors to form the test statistics to account for autocorrelation and possible conditional heteroskedasticity of the regression residuals, which arise due to overlapping observations caused by the forecast horizons. Tables 4.8, 4.9 and 4.10 present the results of OLS estimation at 12, 18 and a 24 month horizons respectively.

At 12 month horizon, we cannot reject the H_0 that $\beta=1$ and $\alpha=0$ for trimmed mean, 58th percentile, WPIEXFL, WPIEX25, WPIEXMOST15, WPISDRP, WPISDS, WPITMBM20, and exponential core measures suggesting that these core measures are unbiased predictors of headline inflation. At 18 month horizon, the results of null of joint restriction are similar to that of 12 month horizon. The difference is that now 58th percentile measure is found to be biased measure and that the null of unbiased predictor can not be rejected for HP-trend, WPISDRPDW and WPIPDW. When we move to 24 month horizon the regression results are also similar to that of earlier horizons. However, note that the results over 18 and 24 month horizon are particularly important for null of unbiasedness

33 The choices of these horizons are the most relevant from the point of view of monetary policy, which is motivated by usual knowledge about the lags in the monetary policy transmission process in India.

test. Since, over this sufficiently longer time horizon one can expect that the transient movement in headline inflation will dispel and it adjust toward its trend level. This can be seen in the improved p-values of wald test for all core measures at both 18 and 24 month horizons compared to that of 12 month horizon in the tables. Further, note that over the 18 and 24 month horizons, the estimated β coefficient value for trimmed means, standard deviation core measures (WPISDS WPISDRPDW, WPISDSDW), WPITMPbP20, and particularly exponential based core measures are very close to 1, suggesting that the deviation $(\pi_t^{Core} - \pi_t)$ of these core measures are correctly measuring the magnitude of transient movement in $(\pi_{t+h} - \pi_t)$.

It is interesting to note that although, the null hypothesis of joint restriction for median measure can be rejected at all horizons but its estimated β value in model is always around one, indicating the source of bias arose from the constant term. This suggest that although median core measure is systematically biased predictor of headline inflation but it correctly measure transient movement in headline inflation at all three horizons i.e. the deviations between this core and headline inflation are not persistent and that headline inflation moves towards median core inflation. This inference can be related to that of Marques *et al* (2000) first two condition result in Table 4.5, where median measure fails to fulfill the unbiased condition but pass the attractor property of core inflation.

Now taking a closer look at \bar{R}^2 values of the unbiased core measures at all the three horizons, the exponential smoothing based core measures clearly outperform over the all other core measures. Equations for both exponential core inflation measures WPIES1 and WPIES2 show highest \bar{R}^2 values of 36 % to 46%. The next best core measures that show high \bar{R}^2 values are WPIEXMost15 and TM (54.5, 25). Among these unbiased core measures, WPIES2 has the highest \bar{R}^2 0.46 at 12 horizon, and WPIEX25% has of the lowest \bar{R}^2 0.00 at 18 month horizon. It should be noted that it is the HP-trend that show the highest \bar{R}^2 value, and is larger than the exponential measures at all the three horizons. Further, note that as we move forecast horizon from 12 to 24 month, the explanatory power of all core measures has considerably reduced. This can be seen in the bar diagram Figure 4.11.

Finally, it should be noted that the signs of estimated β coefficient for all core measures are expected to be positive in the ‘gap’ test model. However, the estimated β coefficient for WPI excluding food items (WPIEXFD) at all horizons show negative sign/coefficient. This implies that WPIEXFD core measure is misleading. Since, negative coefficient indicates that if core inflation is higher than WPI inflation in period t then WPI inflation will be lower in period h , instead of rising more than current WPI inflation level.

A Note on Bias in the Core Measures

It is also important to note that some measures show to be biased predictors of headline inflation within sample analysis mainly due to some of these bias stemming from the intercept term, for example median core measure. As a result, such measures display systematic bias with respect to WPI inflation. At the same time, the constant term in the ‘gap’ test equation can improve/help the predictive performance of the systematically biased core measures. Therefore allowing constant term in the equation, we can implicitly examine in out of sample analysis whether the bias is predictable. If the bias is unpredictable (i.e. if not constant), then the RMSE of out of sample forecast for biased measures should be relatively low compare to unbiased core measures. As a case, we can examine RMSEs of the median core measure. As we show results in a while that the rank of median core measure is the fourth among twenty core measures.

Further, among the conventional exclusion type core measures only WPIEXFL fulfill the joint restriction of unbiasedness test, similarly only one of the persistence core measure (WPIPDW) show insignificance p-value of Wald test at 18 month horizon. As we show latter, core measures; WPIEXFL and WPIDW also perform well in out of sample forecasting particularly at 18 month horizon, suggesting that these measures are unbiased predictor of headline inflation over this horizon. On the other hand, the results on other two conventional exclusion core measures viz., WPIEXFD&FL and WPIEXFD and persistence weighted core measure (WPIPW) show systematically biased measures in sample analysis at all the three horizons and their performance in out of sample forecasting in terms of rank of RMSEs are not superior to that of other measures of core inflation. This suggests that the systematic bias in these measures is constant as both in sample at across forecasting horizons and in out of sample analysis as well.

Out-of-Sample Forecast Evaluation

In this sub-section, we attempt to analyze out of sample forecast evaluation from the ‘gap’ test model. Similar to within sample analysis, our forecast horizons are 12, 18 and 24 months. We use data from 1995M04 to 2002M04 to fit the models which are then used to in the forecasting model. We compute simple static forecast for the period 2002M05 to the end of sample. To evaluate the out-of-sample forecasting accuracy, we first analyze the root mean squared errors (RMSEs) of the forecasts. We then report the rank of RMSEs of forecasts. The rank is based on an average of the RMSE all the three forecast horizons. As before, we then construct Diebold-Mariano test statistic to examine if the observed differences in RMSEs of forecasts are statistically significant at all three horizons.

It should be noted that the HP filter show the highest \bar{R}^2 across all the three forecast horizon in the sample analysis and also fulfills of the UAE conditions. As mentioned earlier, this measure has well known end sample problem. Nevertheless as it has been showing a good trend indicator of WPI inflation, we further examine this trend measure in out of sample evaluation.

The results given in Table 4.11 indicate that RMSEs of forecasts for most of the core measures vary across the three forecast horizons. It shows one of the lowest RMSE for WPIES measures among the alternative core measures at the shorter 12 month horizon but it delivers one of the highest RMSE at 18 and 24 months horizons³⁴. Likewise, Median core measure and persistence double weighted core measure (WPIPDW) perform very well at 18 and 24 month horizons but do relatively badly at the shorter 12 month horizon. On the other hand, trimmed means and particularly HP-trend measure maintain consistence performance at all the three horizons. To assess clear relative performance of different core measures across the three forecast horizons, we compare rank of RMSEs of forecasts, which is based on an average of the RMSEs of all the three forecast horizons. The final column of Table 4.11 reports the ranks of the core measures. It suggests the four core measures, namely, HP-trend, asymmetric trimmed mean (54.5, 25), Median and

³⁴ This results is related to the smoothness of series, if we use lower ‘g’ parameter i.e., more smoothed series, the results would be more consistence, for instance WPIES1 ($g_0 = .105$) show lower RMSE than WPIES2 ($g_0 = .125$) across the all three forecasting horizons (see, Table 4.11).

WPIPDW, rank in that order in terms of predicting future movements in inflation. The WPI excluding food (WPIEXFD), WPIEX25% and standard deviation double weighted core measures (WPISDRPDW WPISDSDW WPISDSDWM) are the worst performers.

Next, consider the results of DM test. The bold figures in the Table 4.11 indicate the lowest RMSE core measure at each forecast horizon. As in within sample performance, the HP trend shows smallest RMSE at 12 and 24 months horizon, whereas WPI excluding fuel (WPIEXFL) is best at 18 month horizon. Accordingly, these measures are chosen as benchmark series for the DM test computation. The Table 4.11 shows that at 12 month forecast horizon, the RMSE of benchmark measure – HP trend is relatively much low to compared all other core measures. As a result, only RMSE of median and RMSE of asymmetric trimmed mean are not significantly different at conventional significance level. Similar results can be seen at 24 month forecast horizon, only RMSE forecast of median and persistence based core measures are statistically not different to that of HP-benchmark measure. On the contrary, at 18 month horizon, due to relatively very close RMSEs between the benchmark-WPIEXFL core measure and other core measures, the null of equal RMSEs can be rejected for the almost all core measures at 5 per cent significance level.

To get a clear image of differences in RMSEs of forecast, we draw 12-months forecast in Figure 4.12 to 4.16, it would clearly appear that the forecast based on HP trend closely track the actual 12-month head headline inflation deviation.

Overall, evidence from DM test and rank of average RMSE indicates that the HP-trend, trimmed mean, median, and double-weighted persistence core measure (WPIPDW) forecast actual headline deviation well. The evidence from predicting analysis indicates that the HP-trend measure outperforms all other core measures. This measure therefore, can be useful core inflation measure specifically as an indicator of future trend inflation.

4.5 Conclusion

This chapter computed several core inflation measures based on different statistical methods. Some of these are computed for first time in Indian case such as persistence weighted, standard deviation double weighted, month by month exclusion (dynamic

trimmed mean) and asymmetric trimmed mean core measures. Subsequently, an empirical evaluation and comparison of those estimated core measures were performed. Just like there is no single universally accepted measure of core inflation, likewise there is no agreed systematic testing framework for selecting best core measure among alternative core measures. The various empirical criteria by which measures of core inflation are evaluated in the literature are implicitly linked to the uses of core inflation in the process of monetary policy. With that in mind, alternative measures of core inflation were evaluated (based on their usefulness from a monetary policy point of view) in a systematic empirical framework.

As a first step, we applied Marques *et al* (2000) 'UAE' tests. Only asymmetric trimmed mean and HP-trend measure passed all the three tests. To evaluate further the relevance of core measures from a monetary policy point of view, we then applied two standard test of core inflation viz., tracking trend inflation and forecasting future transient movement in inflation. These two criteria are used to evaluate to what extent different core inflation indicators are useful in providing information about current underlying trend inflation and future movement in headline inflation. Before applying trend inflation criterion, we selected reference trend inflation measures according to the UAE tests results. The selected trend measures in the RMSE evaluation process therefore, guaranteed that they possess necessary properties of underlying trend inflation. The results suggest that the trend based exponential based core measures, and asymmetric trimmed mean and standard deviation double weighted core measures did the best job in tracking trend inflation of WPI. The results were robust with respect to two selected reference trend inflation viz., CMA-37 and HP trend inflation.

Taken together the evidence from within sample analysis and out of sample forecasting evaluation of 'gap' test model, we found that the results varied across the forecasting horizons. In sample analysis, except conventional ex-food and fuel measures and persistence weighted core measure (WPIPW), most of the core measures perform well. Evidence from the DM test and Rank of average RMSEs of out of sample forecast suggest that the HP-trend, asymmetric trimmed mean, median, and double weighted-persistence (WPIPDW) core measures forecasted actual headline deviation well.

Considering the importance of unbiasedness property of core inflation, the particular attention has been focused on systematic bias in the core measures. Specifically, we examined this issue, besides joint restrictions test of static regression (first test of Marques *et al*), in the within sample and out of sample analysis within the ‘gap’ model framework. The results are varied across the all three forecasting horizon for all measures. As a case, we note two results. One is that bias in the median measure was not constant and second, the conventional exclusion based core measures (WPIEXFD&FL and WPIEXFD) and persistence weighted core measure (WPIPW) were found to be consistently biased measures across all the three forecasting horizons.

The asymmetric trimmed mean and HP-trend measures consistently performed well on across the board and outperformed all other measures of core inflation. However, there is an emerging view in the literature that “each measure of core inflation can provide some particular insight into how inflation is evolving”. In this regard, core measures based on objective approaches of exclusion viz., month by month exclusion (WPIMBM), WPIEX25% and WPIEXMost15 core measures are worth considering in analyzing and identifying the nature of persistency and source of shocks in the headline inflation development. Its is here worth mention that recent demand shock to oil prices and persistency in commodity prices particularly in an emerging economy like India suggest that monetary authority should consider different useful core inflation indicators in the analyzing the underlying inflation development for the conduct of monetary policy. It should also be noted that the conventional ex-food and fuel core measures did not satisfy any of the basic property of core inflation. It is therefore important to consider some representative core measures that can be selected based on their empirical performance. Such representative measures of core inflation can be used to generate overall outlook on dynamics of inflation development.

Overall, we conclude that the asymmetric trimmed mean, WPIEX25%, WPIEXMBM20, double weighted standard deviation based core measures (WPISDSDWM, WPISDRPDWM) and median core measures can be used in analyzing and tracking underlying trend inflation development while trend based HP filters and exponential measures can be useful indicators of future trend inflation for the conduct of monetary policy India.

Table 4.1: Summary of Cross-Sectional Distribution of Year on Year Price Changes in India

	WPI	Sta.Dev	SKEWNESS	KURTOSIS
Mean	5.37	9.41	1.34	14.18
Median	5.12	8.67	1.07	6.27

Table 4.3: Comparative Summary Statistics of Exclusion Based Core Inflation Measures

	Mean	p-value of wald-test,(unbiasedness test)	Std. Dev.	C.V	Std. of first diff
WPI	5.37	---	2.19	0.41	0.82
WPIEXPA	5.30	0.00	2.42	0.46	0.86
WPIEXFOOD	5.33	0.00	2.52	0.47	0.88
WPIEXFL	4.70	0.00	2.48	0.53	0.74
WPIExFD&FL	4.50	0.00	2.75	0.61	0.74
WPIEX25%	5.35	0.77	2.11	0.39	0.77
WPIEX20%	5.44	0.07	2.32	0.43	0.80
WPIEXMost15	4.74	0.00	1.87	0.39	0.63

Table 4.2: Volatility Analysis of 69 Components of WPI Index

69 Component of WPI ordered According to Rank of Sta. dev (based on y-o-y inflation)	Components % of Exclusion on the Basis of y-o-y Inflation of Volatility Out of $\mu \pm 1.5 \rho$	Average (based on y-o-y inflation)	Sta. dev (based on y-o-y inflation)	Ranking of Sta. dev (based on y-o-y inflation)	Sta. dev (based on seasonally adjusted m-o-m inflation)	Ranking of Sta. dev (based on seasonally adjusted m-o-m inflation)	AR (p)- Persistent (based on Seasonally Adjusted m-o-m inflation)
Metallic Minerals	53.85	23.6	50.13	1	8.27	2	0.15
Manufacture of Common Salts	49.7	10.73	36.49	2	4.91	3	0.17
Vegetables	45.56	8.06	23.65	3	8.72	1	-0.19
Other Food Articles(Tea& Coffee)	49.7	6.22	19.27	4	4.54	6	0.18
Basic Heavy Organic Chemical	43.79	4.26	18.1	5	4.3	7	0.53
Wood & Wood Products	13.61	6.46	15.93	6	2.86	12	0.41
Oil Cakes	29.59	8.32	15.69	7	3.37	10	0.19
Tea & Coffee Processing	32.54	5.91	15.17	8	4.06	9	0.05
Canning, Preserving & Processing of fish	17.16	9.78	14.62	9	4.65	5	-0.12
Jute Hemp & Mesta Textiles	31.95	6.36	14.24	10	2.84	13	0.22
Fibres	34.91	3.64	13.98	11	2.79	17	0.31
Condiments & Spices	30.18	6.41	13.5	12	2.45	2	0.21
Printing & Publishing of Newspapers, Periodicals	11.24	7.42	12.97	13	2.82	16	0.29
Edible Oils	26.04	4.53	12.37	14	1.91	35	0.39
Minerals Oils Petrol and Gas	14.79	11.05	11.96	15	2.9	11	0.11
Oil Seeds	20.12	5.96	11.6	16	2.25	22	0.29
Iron & Steel	18.34	8.95	11.49	17	2.42	21	0.19
Basic Heavy Inorganic Chemical	14.2	5.54	11.32	18	2.05	30	0.53
Ferro Alloys	18.34	3.51	11.29	19	2.7	18	0.17
Fruits	21.3	7.69	11.03	20	4.88	4	-0.1
Pulses	22.49	6.12	10.92	21	2.5	19	0.33
Non-Ferrous Metals	19.53	6	10.63	22	1.52	44	0.63
Turpentine, Synthetic Resins and Plastic materials	16.57	2.91	10.3	23	4.19	8	-0.33
Grain Mill Products	13.02	6.61	10.16	24	2.05	31	0.27
Sugar,Khandsari & Gur	20.71	3.14	10.05	25	1.91	34	0.61
Other Rubber & Plastic Products	15.98	4.27	9.98	26	2.83	15	0.14
Paper & Pulp	10.06	4.49	9.93	27	1.3	50	0.6

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Foundries for Casting Forging & Structural	8.28	8.01	9.11	30	1.84	37	0.15
Cotton Yarn	13.02	1.94	8.65	31	2.11	26	0.3
Malt liquor	8.28	6.06	8.54	32	2.09	27	0.19
Cement	10.65	5.32	8.12	33	1.84	36	0.29
Pesticides	14.2	-0.07	8.1	34	1.83	38	0.28
Drugs & Medicines	7.1	7.02	8.04	35	1.62	41	0.23
Glass Earthenware Chinaware & their products	8.88	3.07	8.03	36	1.77	39	0.18
Manufacture of Board	8.88	3.2	7.95	37	2.12	25	-0.02
Man Made Fibre	11.24	-0.24	7.83	38	1.59	42	0.32
Cement Slate & Graphite Products	5.92	5.21	7.7	39	1.57	43	0.25
Tyres & Tubes	6.51	3.7	7.4	40	1.39	46	0.12
Leather & Leather Products	9.47	3.34	7.4	41	1.94	33	-0.06
Coal Mining	8.28	6.69	7.36	42	2.06	29	0.03
Pipes Wires Drawing & Others	4.73	6.29	7.27	43	1.34	48	0.53
Other Minerals	7.69	2.07	6.8	44	2.07	28	0.04
Cereals	4.14	5.42	6.68	45	1.04	58	0.38
Eggs,Meat & Fish	4.73	5.83	6.65	46	2.13	24	-0.01
Woolen Textiles	4.14	2.26	6.24	47	2	32	0.09
Structural Clay Products	4.14	5.99	5.96	48	1.43	45	0
Dairy Products	2.96	5.7	5.95	49	1.13	55	0.27
Electricity	2.37	6.63	5.71	50	1.69	40	-0.19
Bakery Products	5.33	4.7	5.68	51	1.36	47	0.04
Other Food Products n.e.	0.59	5.79	5.44	52	0.93	62	0.21
Paints, Varnishes & Laquers	0	3.39	5.35	53	1.2	54	0.13
Perfumes, Cosmetics, Toiletries etc	1.18	5.85	4.91	54	1.22	51	-0.01
Electrical Machinery	0	2.75	4.79	55	0.72	67	0.39
Dyestuffs & Indigo	1.18	0.74	4.74	56	1.08	57	0.47
Locomotives Railway Wagon & Parts	6.51	2.28	4.69	57	0.9	63	0.27
Cotton Cloth (Mills)	0.59	2.83	4.58	58	0.79	65	0.32
Fertilisers	1.18	3.95	4.28	59	1.32	49	0.07
Other Food Articles	0	5.56	4.16	60	1.22	52	0.18
Manufacture of Bidi, Cigarettes, Tobacco & Zarda	1.18	7.42	4.15	61	0.94	60	0.02
Matches, Explosives and Other Chemicals	0.59	3.5	3.85	62	0.94	61	0.24
Plastic Products	0	2.92	3.81	63	1.02	59	0.17
Cocoa, Chocolate Sugar & Confectionery	0	3.43	3.7	64	1.11	56	0.22
Metal Products	0	3.01	3.59	65	0.76	66	0.48
Milk	0	5.4	3.54	66	1.21	53	0.05
Man Made Cloth	0	1.67	3.08	67	0.81	64	-0.07
Non-Electrical Machinery & Parts	0	4.83	2.68	68	0.51	68	0.2
Motor Vehicles, Motorcycles, Scooters, bicycles & parts	0	3.68	2.59	69	0.48	69	0.18

Table 4.4: ADF-Unit Root Test of Core Inflation Measures

Core Inflation Measures	P-value of ADF test*	Lag@	Max Lag	Obs
WPI Inflation	0.0005	1	13	167
TM(54.5,25)	0.0005	1	13	167
TM (55,20)	0.0006	1	13	167
Median	0.0012	0	13	168
58 th Percentile	0.0010	0	13	168
WPIEXFL	0.0032	1	13	167
WPIEXFOOD	0.0008	1	13	167
WPIEXFD&FL	0.0036	2	13	166
WPIEXPA	0.0020	1	13	167
WPIEXMOST15	0.0010	2	13	166
WPIEX20%	0.0038	1	13	167
WPIEX25%	0.0016	1	13	167
WPITMPBP5	0.0046	0	13	168
WPITMPBP10	0.0011	0	13	168
WPITMPBP15	0.0040	0	13	168
WPITMPBP20	0.0000	3	13	165
WPITMPBP25	0.0000	3	13	165
WPISDRP	0.0023	2	13	166
WPISDRPDW	0.0007	1	13	167
WPISDRPDWM	0.0007	1	13	167
WPISDRPM	0.0017	2	13	166
WPISDS	0.0027	2	13	166
WPISDSDW	0.0007	1	13	167
WPISDSDWM	0.0010	1	13	167
WPISDSM	0.0020	2	13	166
WPIPW	0.0019	2	13	166
WPIPDW	0.0001	3	13	165
WPIES1 (g=0.125)	0.0001	2	13	166
WPIES2 (g=0.105)	0.0000	2	13	166

*With 1 % significance level, the null hypothesis of ADF unit root can be rejected for all inflation measures
 @ Lag length are chosen basis on schwarz information criterion (SIC)

Table 4.5: Unbiasedness, “Attraction” and Exogeneity (UAE) Criteria

	Test (i) : Unbiased property	Test (ii) : Attractor Property	Test(iii-a): weak Exogeneity property	Test (iii-b): Strong Exogeneity Property	
Core Inflation Measures	p-values of wald test	p-values of t-test	p-values of t-test	p-values of wald test	Conclusion
WPIEXPA	0.00	0.20	0.51	0.36	Fail test (i) & (ii)
WPIEXFD	0.00	0.44	0.29	0.35	Fail test (i) & (ii)
WPIExFD&FL	0.00	0.43	0.42	0.00	Fail test (i) (ii) (iii-b)
WPIEXFL	0.00	0.79	0.29	0.22	Fail all test (i) & (ii)
WPIEX25%	0.77	0.17	0.94	0.58	Fail test (ii)
WPIEX20%	0.07	0.11	0.93	0.58	Fail test (ii)
WPIEXMost15	0.00	0.15	0.18	0.01	Fail test (i) (ii) (iii-b)
WPISDRP	0.00	0.01	0.00	0.00	Fail test (i) (iii-a) & (iii-b)
WPISDRPDW	0.00	0.02	0.04	0.02	Fail test (i) (iii-a) & (iii-b)
WPISDS	0.00	0.01	0.01	0.00	Fail test (i) (iii-a) & (iii-b)
WPISDSDW	0.00	0.02	0.48	0.11	Fail test (i)
WPISDSM	0.00	0.02	0.53	0.01	Fail test (i) & (iii-b)
WPISDSDWM	0.00	0.02	0.30	0.12	Fail test (i)
WPISDRPM	0.00	0.02	0.61	0.02	Fail test (i) & (iii-b)
WPISDRPDWM	0.00	0.01	0.28	0.22	Fail test (i)
WPIPW	0.00	0.79	0.11	0.01	Fail test (i) (ii) (iii-b)
WPIPDW	0.00	0.62	0.29	0.18	Fail test (i) & (ii)
TM (54.5, 25)	0.23	0.05	0.65	0.22	O K
TM (55, 20)	0.12	0.02	0.86	0.05	O K
Median	0.00	0.01	0.43	0.00	Fail test (i) & (iii-b)
WPIMBM5	0.00	0.04	0.22	0.00	Fail test (i) & (iii-b)
WPIMBM10	0.00	0.01	0.52	0.00	Fail test (i) & (iii-b)
WPIMBM15	0.00	0.14	0.39	0.04	Fail test (i) (ii) (iii-b)
WPIMBM20	0.00	0.48	0.12	0.02	Fail test (i) (ii) (iii-b)
WPIMBM25	0.00	0.62	0.08	0.00	Fail test (i) (ii) (iii-b)
WPIES1	0.73	*	*		
WPIES2	0.42	*	*		
CMA37	0.25	0.04	0.23	0.31	O K
HP filter (14000)	0.58	0.00	0.50	0.05	O K

Notes: The Exogeneity property (iii) is carried out in two steps: weak exogeneity (iii-a) and strong exogeneity (iii-b), for detail see section 3.4.2 in the chapter -3.

In the last column, conclusions are drawn on conventional significance level.

OK - indicate corresponding underlying inflation measures satisfied all three tests of UAE.

* Not estimable

Table 4.6: Summary Statistics of Core Inflation Measures

Core Inflation Measures	Mean	Std. Dev.	Std. Dev. of first diff	CV (Sta.Dev/Mean)
WPI	5.37	2.19	0.82	0.41
TM (54.5,25)	5.16	1.89	0.74	0.36
Median	3.80	1.69	0.88	0.44
58 th Percentile	4.95	1.92	0.97	0.39
WPIEXPA	5.30	2.42	0.86	0.46
WPIEXFOOD	5.33	2.52	0.88	0.47
WPIEXFDANDFL	4.50	2.75	0.74	0.61
WPIEXFL	4.70	2.48	0.74	0.53
WPIEX25%	5.35	2.11	0.77	0.39
WPIEX20%	5.44	2.32	0.80	0.43
WPIEXMOST15	4.74	1.87	0.63	0.39
WPISDRP	4.57	1.96	0.45	0.43
WPISDRPDW	4.96	1.75	0.60	0.35
WPISDS	4.54	1.95	0.45	0.43
WPISDSDW	4.92	1.73	0.59	0.35
WPISDSM	4.56	2.10	0.44	0.46
WPISDSDWM	4.78	1.76	0.55	0.37
WPISDRPM	4.63	2.16	0.47	0.47
WPISDRPDWM	4.91	1.84	0.61	0.37
WPIPW	4.76	3.11	0.73	0.65
WPIPDW	4.57	2.60	0.78	0.57
WPITMPBP5	4.61	1.94	0.92	0.42
WPITMPBP10	4.30	1.77	0.91	0.41
WPITMPBP15	4.60	1.91	0.88	0.41
WPITMPBP20	4.72	2.01	0.85	0.43
WPITMPBP25	4.80	2.06	0.91	0.43
WPIES1	5.33	1.18	0.24	0.22
WPIES2	5.31	1.06	0.20	0.19
HP	5.36	0.85		0.16

Table 4.7 Ability of Tracking the Trend in WPI Inflation

Core Inflation Measures	MAD – CMA37	RMSE – CMA37	p-value DM test	RMSE – HP	p-value DM test
TM (54.5,25)	0.91	1.21	-	1.49	-
Median	1.75	2.02	0.00	2.06	0.00
58 th Percentile	1.14	1.47	0.01	1.46	0.87*
WPIExPA	1.47	1.92	0.01	2.21	0.00
WPIEXFOOD	1.50	1.93	0.00	2.27	0.00
WPIEXFDANDFL	1.91	2.29	0.00	2.43	0.00
WPIEXFL	1.73	2.02	0.00	2.08	0.00
WPIEX25%	1.22	1.64	0.06*	1.88	0.01
WPIEX20%	1.31	1.81	0.08*	2.09	0.01
WPIEXMOST15	1.13	1.38	0.26*	1.53	0.76*
WPISDRP	1.21	1.49	0.06*	1.54	0.74*
WPISDRPDW	1.09	1.34	0.34*	1.46	0.81*
WPISDS	1.23	1.50	0.05*	1.54	0.76*
WPISDSDW	1.10	1.34	0.32*	1.44	0.68*
WPISDSM	1.31	1.59	0.02	1.64	0.36*
WPISDSDWM	1.11	1.12	0.18*	1.44	0.69*
WPISDRPM	1.29	1.59	0.03	1.66	0.26*
WPISDRPDWM	1.11	1.35	0.18*	1.51	0.81*
WPIPW	2.06	2.47	0.00	2.60	0.00
WPIPDW	1.94	2.26	0.00	2.34	0.00
WPITMPbP5	1.30	1.66	0.00	1.74	0.03
WPITMPbP10	1.38	1.71	0.00	1.72	0.16*
WPITMPbP15	1.18	1.53	0.00	1.71	0.05*
WPITMPbP20	1.12	1.40	0.01	1.74	0.00
WPITMPbP25	1.20	1.46	0.01	1.79	0.00
WPIES1	0.67	0.83	-	0.90	-
WPIES2	0.60	0.74	-	0.82	-

Notes: The DM (Diebold-Mariano (1995) test statistic considers the null hypothesis of equal root mean squared error (RMSE) against the alternative hypothesis that the RMSE of a benchmark series is lower. Test statistics were constructed using the Newey-West (1987) covariance matrix estimator.

H0: RMSE of Core Measure (TM (54.5, 25) = RMSE Model in Row

H1: RMSE of Core Measure (TM (54.5, 25) \neq RMSE Model in Row

* with 5 % significance level the null hypothesis of equal root mean squared error (RMSE) is not rejected.

Table 4.8: In Sample Evaluation of ‘gap’ Model at 12 Month Horizon

Core inflation Measures	Coefficient (α)	Coefficient (β)	p-value of wald test ($\alpha = 0, \beta = 1$)	Value of \bar{R}^2
TM (54.5,25)	0.38	1.56	0.27*	0.20
TM (55, 20)	0.29	1.69	0.17*	0.20
Median	1.87	1.30	0.00	0.19
58 th Percentile	0.31	0.88	0.61*	0.14
WPIEXFOOD	-0.02	-0.18	0.16	0.00
WPIEXFDANDFL	0.42	0.45	0.00	0.04
WPIEXFL	0.39	0.54	0.09*	0.04
WPIEX25	-0.04	0.63	0.82*	0.02
WPIEXMOST15	0.87	1.51	0.34*	0.19
WPISDRP	0.63	0.84	0.16*	0.11
WPISDRPDW	0.68	2.06	0.02	0.20
WPISDS	0.68	0.86	0.15*	0.12
WPISDSDW	0.78	2.08	0.02	0.21
WPISDSDWM	1.22	2.29	0.01	0.27
WPISDRPDWM	1.16	2.81	0.00	0.28
WPIPW	-0.01	0.00	0.00	-0.01
WPIPDW	0.31	0.37	0.04	0.02
WPITMPbP20	0.82	1.35	0.38*	0.16
WPIES1	-0.01	1.33	0.21*	0.43
WPIES2	-0.01	1.34	0.15*	0.46
HP Filter	-0.18	1.76	0.00	0.68

* With 5 per cent significance level null of unbiased predictor is not rejected

Standard errors (s.e) were calculated using the Newey-West (1987) covariance matrix estimator to account for autocorrelation of the regression residuals.

Table 4.9: In Sample Evaluation of ‘gap’ Model at 18 Month Horizon

Core inflation Measures	Coefficient (α)	Coefficient (β)	p-value of wald test ($\alpha = 0, \beta = 1$)	Value of \bar{R}^2
TM (54.5,25)	0.30	1.06	0.78*	0.12
TM (55,20)	0.25	1.21	0.74*	0.13
Median	1.39	0.93	0.00	0.12
58 th Percentile	0.30	0.62	0.00	0.08
WPIEXFOOD	-0.01	-0.92	0.00	0.06
WPIEXFDANFL	0.46	0.41	0.01	0.04
WPIEXFL	0.63	0.76	0.28*	0.12
WPIEX25	0.01	0.25	0.43*	0.00
WPIEXMOST15	0.88	1.49	0.22*	0.25
WPISDRP	0.64	0.78	0.00	0.13
WPISDRPDW	0.48	1.37	0.54*	0.11
WPISDS	0.67	0.79	0.09*	0.13
WPISDSDW	0.55	1.39	0.46*	0.12
WPISDSDWM	1.07	1.93	0.04	0.24
WPISDRPDWM	1.00	2.31	0.01	0.24
WPIPW	0.16	0.18	0.00	0.01
WPIPDW	0.64	0.67	0.09*	0.10
WPITMPbP20	0.79	1.25	0.25*	0.18
HP Filter	-0.04	1.22	0.58*	0.41
WPIES1	0.00	0.98	0.99*	0.30
WPIES2	0.00	1.00	1.00*	0.30

* With 5 per cent significance level null of unbiased predictor is not rejected

Table 4.10: In Sample Evaluation of ‘gap’ Model at 24 Month horizon

Core Inflation Measures	Coefficient (a)	Coefficient (β)	p-value of wald test (α = 0, β = 1)	Value of \bar{R}^2
TM (54.5,25)	0.19	0.66	0.55*	0.04
TM (55,20)	0.14	0.69	0.69*	0.04
Median	1.16	0.80	0.01	0.09
58 th Percentile	0.20	0.45	0.01	0.04
WPIEXFOOD	-0.03	-0.94	0.00	0.07
WPIEXFDANDFL	0.12	0.10	0.00	0.00
WPIEXFL	0.44	0.49	0.02	0.04
WPIEX25	0.01	-0.06	0.05*	-0.01
WPIEXMOST15	0.34	0.57	0.27*	0.03
WPISDRP	0.52	0.63	0.03	0.08
WPISDRPDW	0.26	0.78	0.67*	0.03
WPISDS	0.54	0.64	0.03	0.08
WPISDSDW	0.31	0.82	0.65*	0.04
WPIPW	0.21	0.27	0.00	0.03
WPIPDW	0.52	0.56	0.04	0.06
WPITMPbP20	0.46	0.74	0.32*	0.06
WPISDSDWM	0.71	1.25	0.40*	0.09
WPISDRPDWM	0.59	1.32	0.54*	0.07
WPIES1	0.02	1.00	1.00*	0.31
WPIES2	0.02	1.02	0.97*	0.34
HP Filter	0.01	1.22	0.50*	0.38

Note: Standard errors (s.e) were calculated using the Newey-West (1987) covariance matrix estimator to account for autocorrelation of the regression residuals.

*with 5 per cent significance level null of unbiased predictor is not rejected

Table 4.11: Out Sample Forecasting Evaluation from ‘gap’ Model

Forecast horizon	<i>h</i> =12		<i>h</i> =18		<i>h</i> =24		Ranking of average RMSEs
Core Inflation Measures	RMSE	DM test p-value	RMSE	DM test p-value	RMSE	DM test p-value	
TM (54.5,25)	3.05	0.03	2.62	0.72*	3.18	0.02	-
TM (55,20)	3.06	0.05*	2.62	0.72*	3.18	0.02	2
Median	3.27	0.08*	2.66	0.68*	3.09	0.05*	3
58 th Percentile	3.23		2.60		3.21		6
WPIEXFOOD	3.38	0.02	2.86	0.09*	3.41	0.01	17
WPIEXFDANDFL	3.26	0.02	2.61	0.28*	3.27	0.01	8
WPIEXFL	3.29	0.01	2.50	—	3.28	0.03	7
WPIEX25	3.88	0.02	3.00	0.12*	3.26	0.01	18
WPIEXMOST15	3.25	0	2.83	0.16*	3.42	0.01	13
WPISDRP	3.22	0.01	2.82	0.24*	3.20	0.03	9
WPISDRPDW	4.16	0	3.65	0.02	3.42	0.01	19
WPISDS	3.22	0.01	2.84	0.22*	3.21	0.02	10
WPISDSDW	4.22	0	3.76	0.01	3.46	0.01	20
WPISDSDWM	3.13	0	3.09	0.09*	3.31	0.01	16
WPISDRPDWM	3.15	0	2.86	0.19*	3.23	0.03	9
WPIPW	3.39	0.02	2.73	0.19*	3.16	0.07*	11
WPIPDW	3.28	0.01	2.61	0.61*	3.10	0.39*	4
WPITMPbP20	3.53	0.02	2.73	0.40*	3.25	0.01	14
WPIES1	2.91	0.01	3.25	0.14*	3.36	0.02	15
WPIES2	2.89	0.02	3.22	0.17*	3.29	0.02	12
HP Filter	2.21	—	2.83	0.46*	2.78	—	1

Notes: the bold figure indicate lowest RMSEs of forecast at each horizon.

The DM (Diebold-Mariano (1995) test statistic considers the null hypothesis of equal root mean squared error (RMSE) against the alternative hypothesis that the RMSE of a relevant benchmark series is lower. Test statistics were constructed using the Newey-West (1987) covariance matrix estimator.

* With 5 % significance level the null hypothesis of equal root mean squared error (RMSE) is not rejected.

WPI Inflation and Alternative Core Inflation Rate:

Figure 4.1

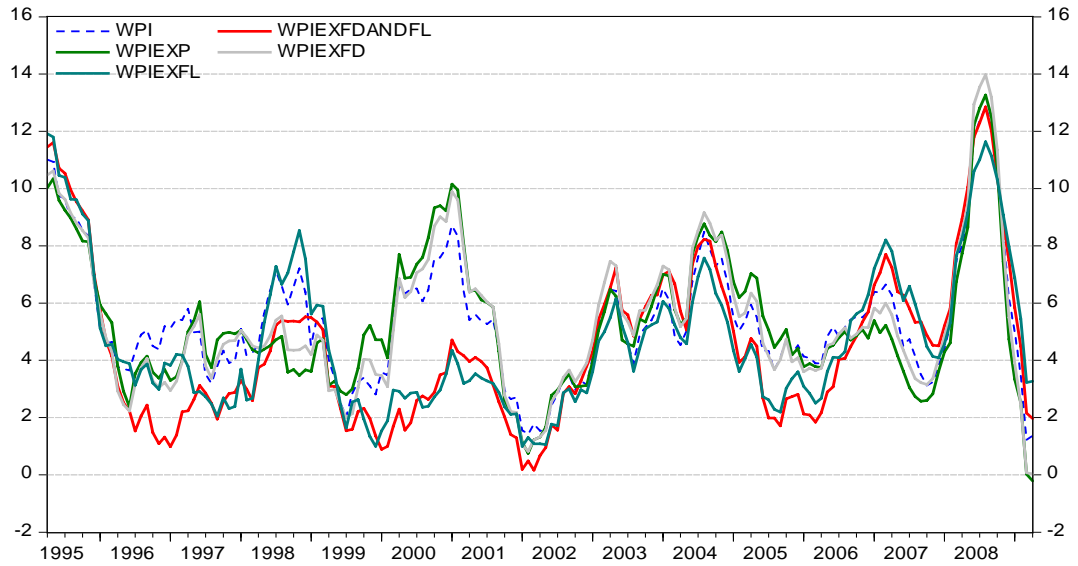


Figure 4.2

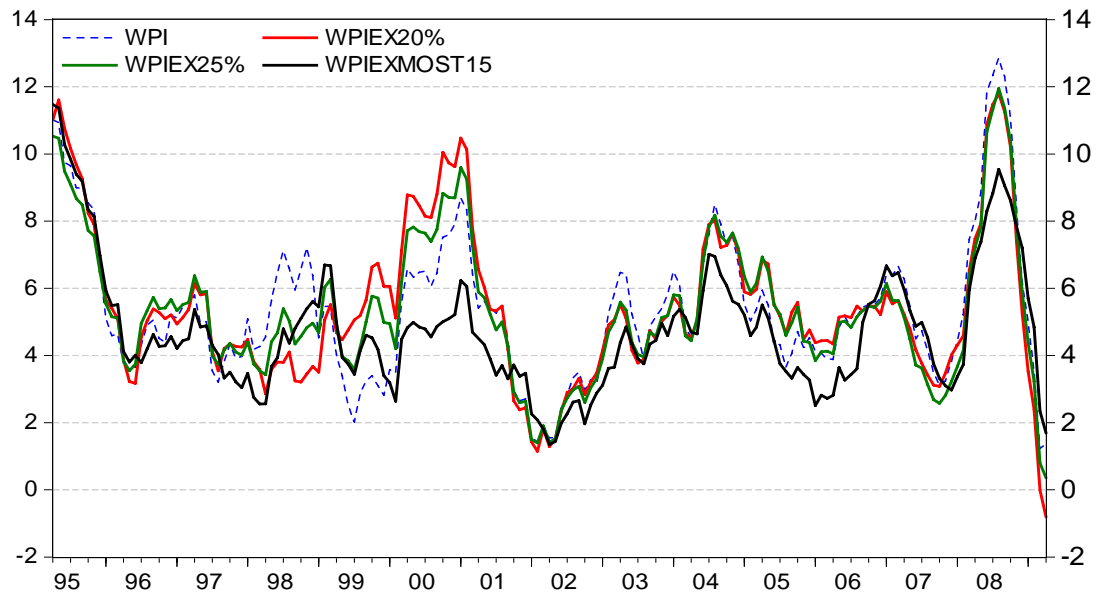


Figure 4.3

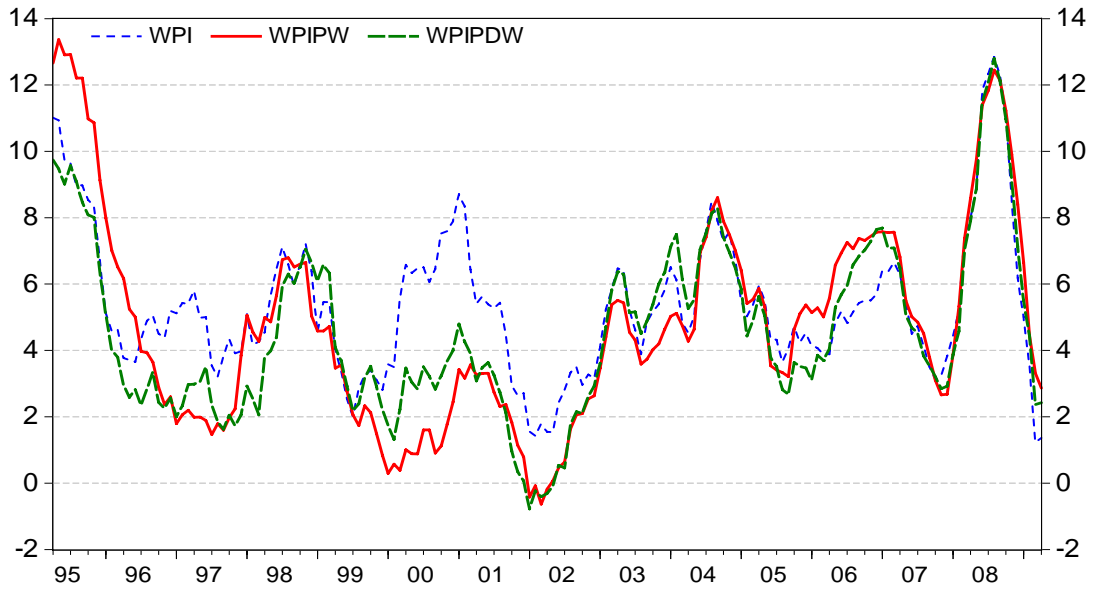


Figure 4.4

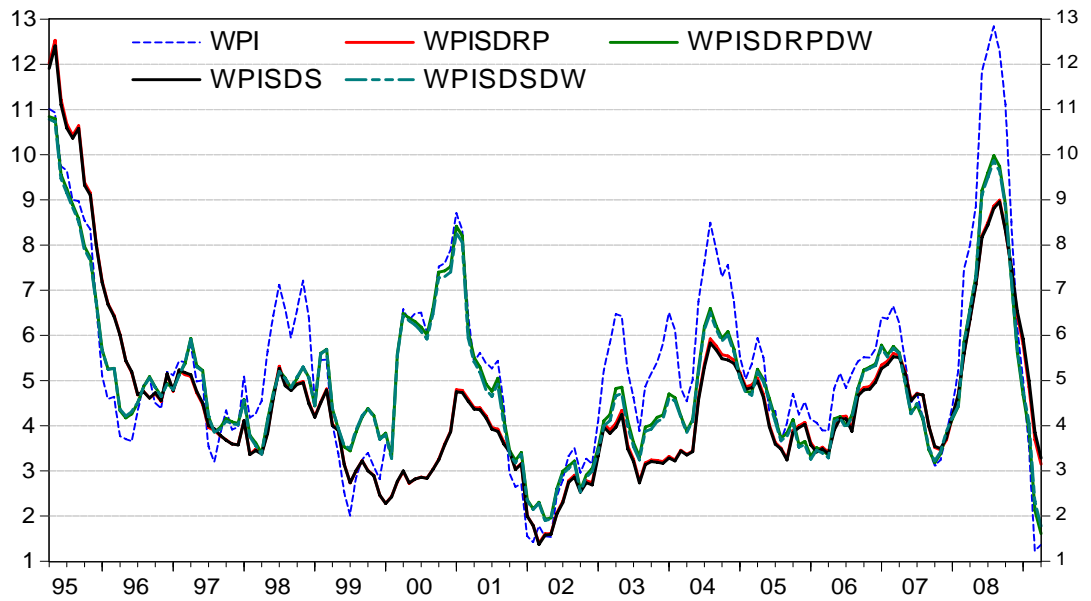


Figure 4.5

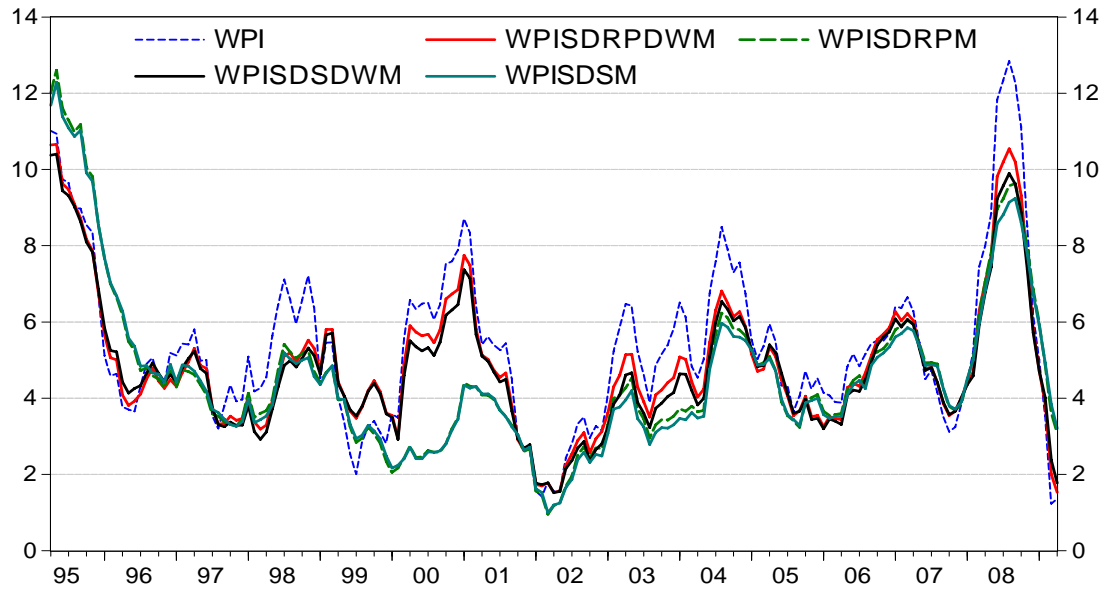


Figure 4.6

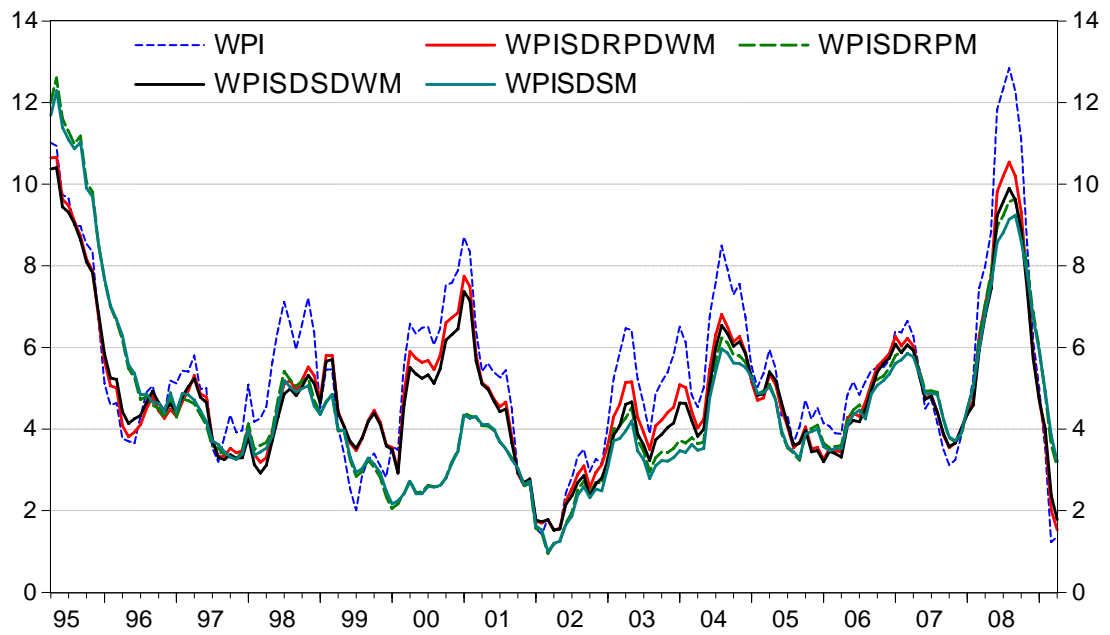


Figure 4.7

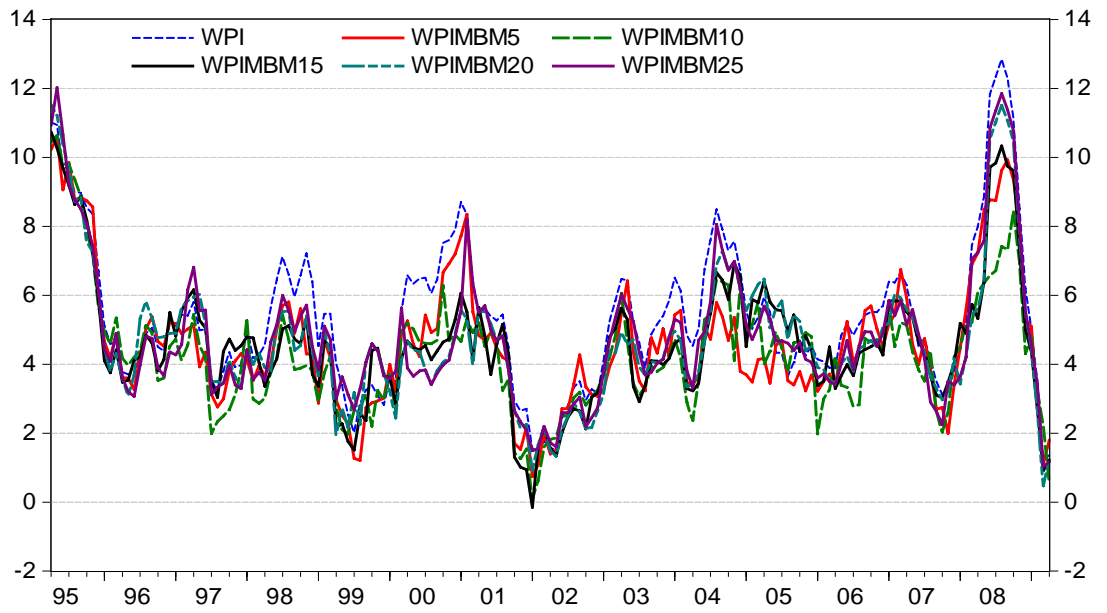


Figure 4.8

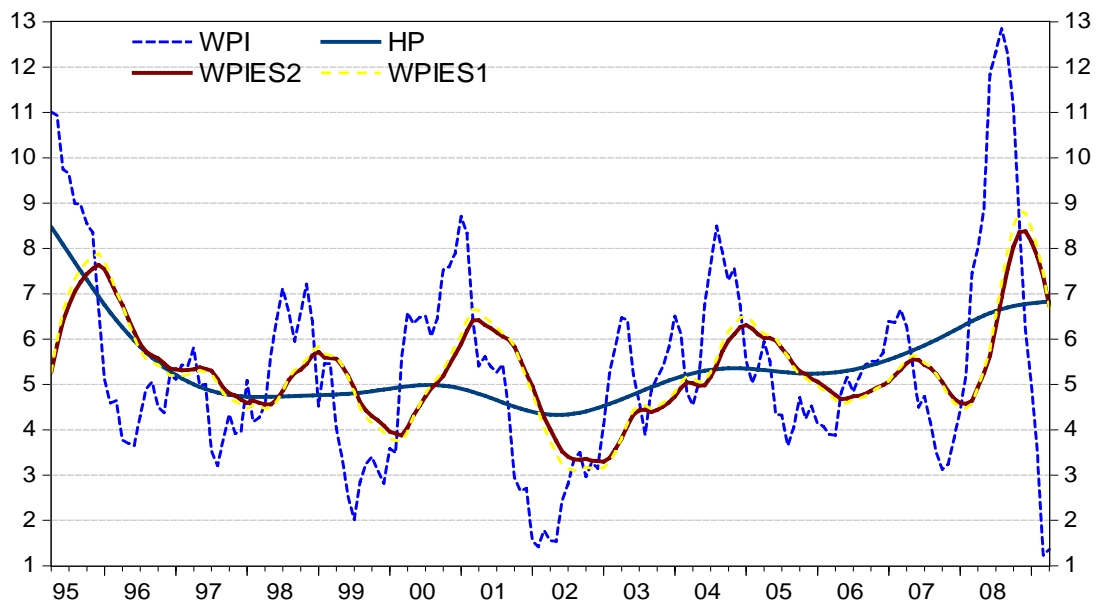


Figure 4.9

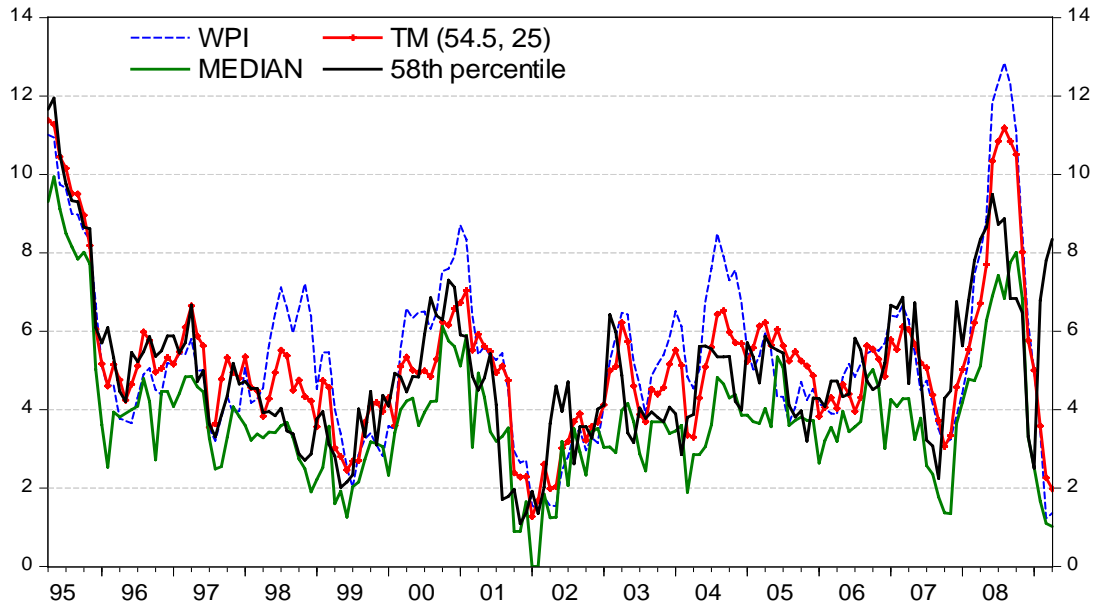


Figure 4.10: 37-months Center Moving Average of WPI Inflation (CMA37) and HP -trend Estimate of WPI Inflation

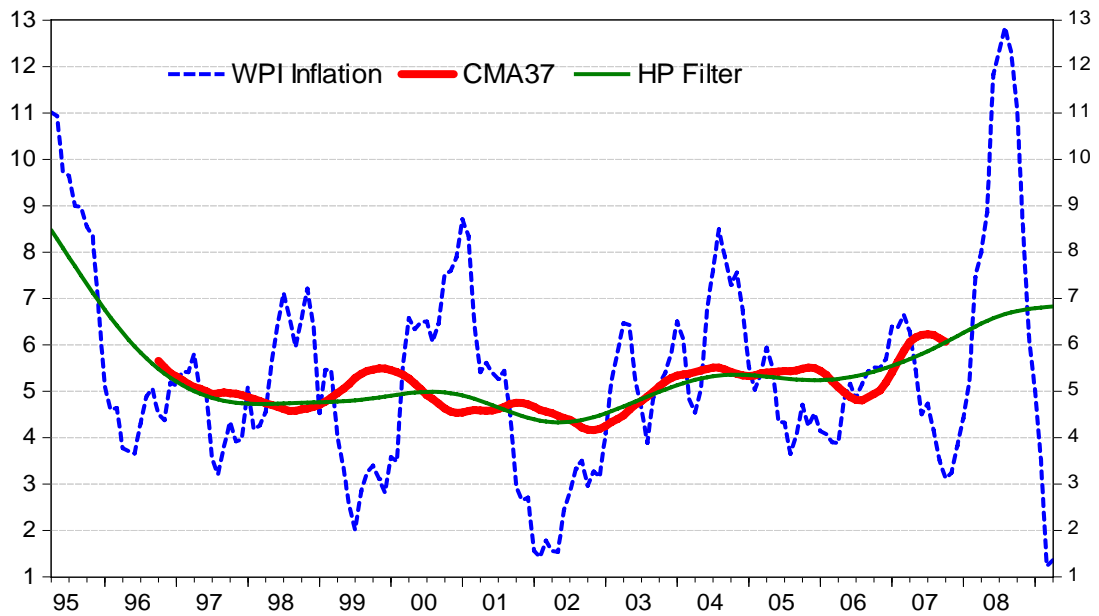


Figure 4.11: Adjusted (R^2) of Various Core Measures at Three Forecast Horizon (h)

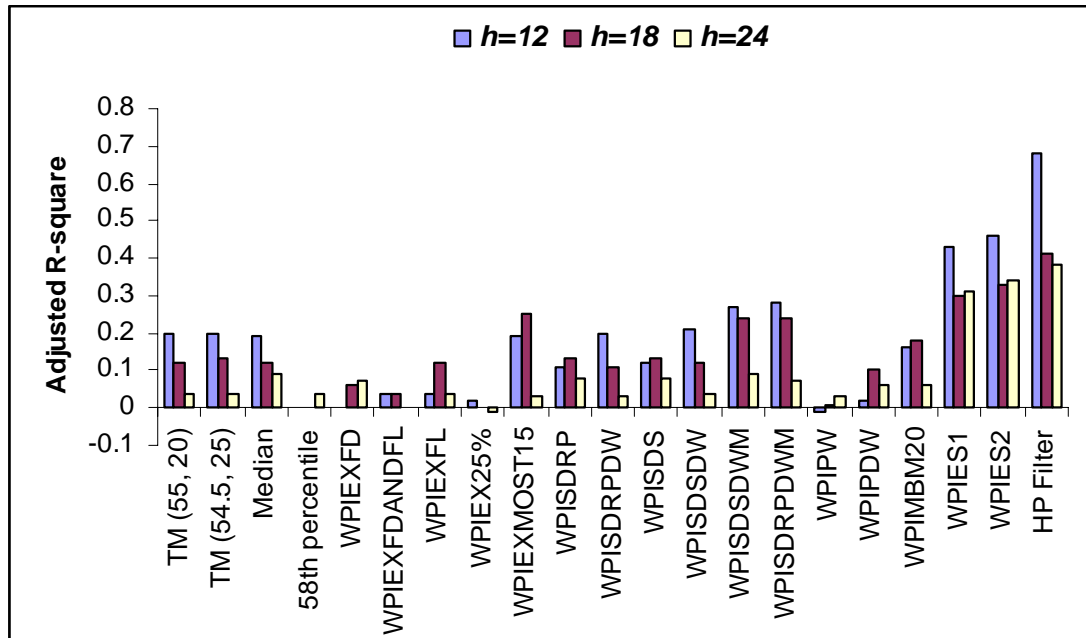


Figure 4.12: Comparison of Forecast

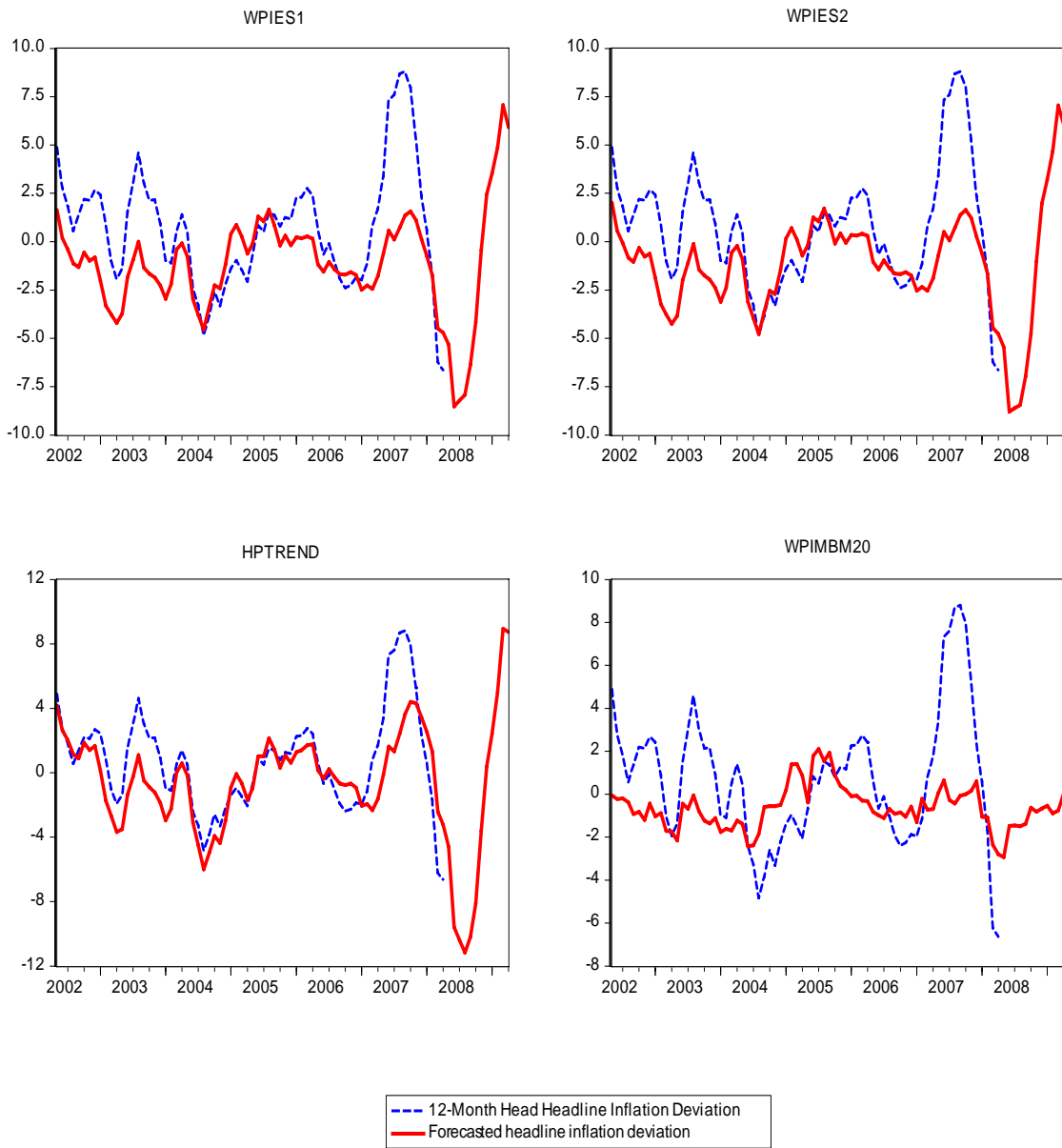


Figure 4.13: Comparison of Forecast

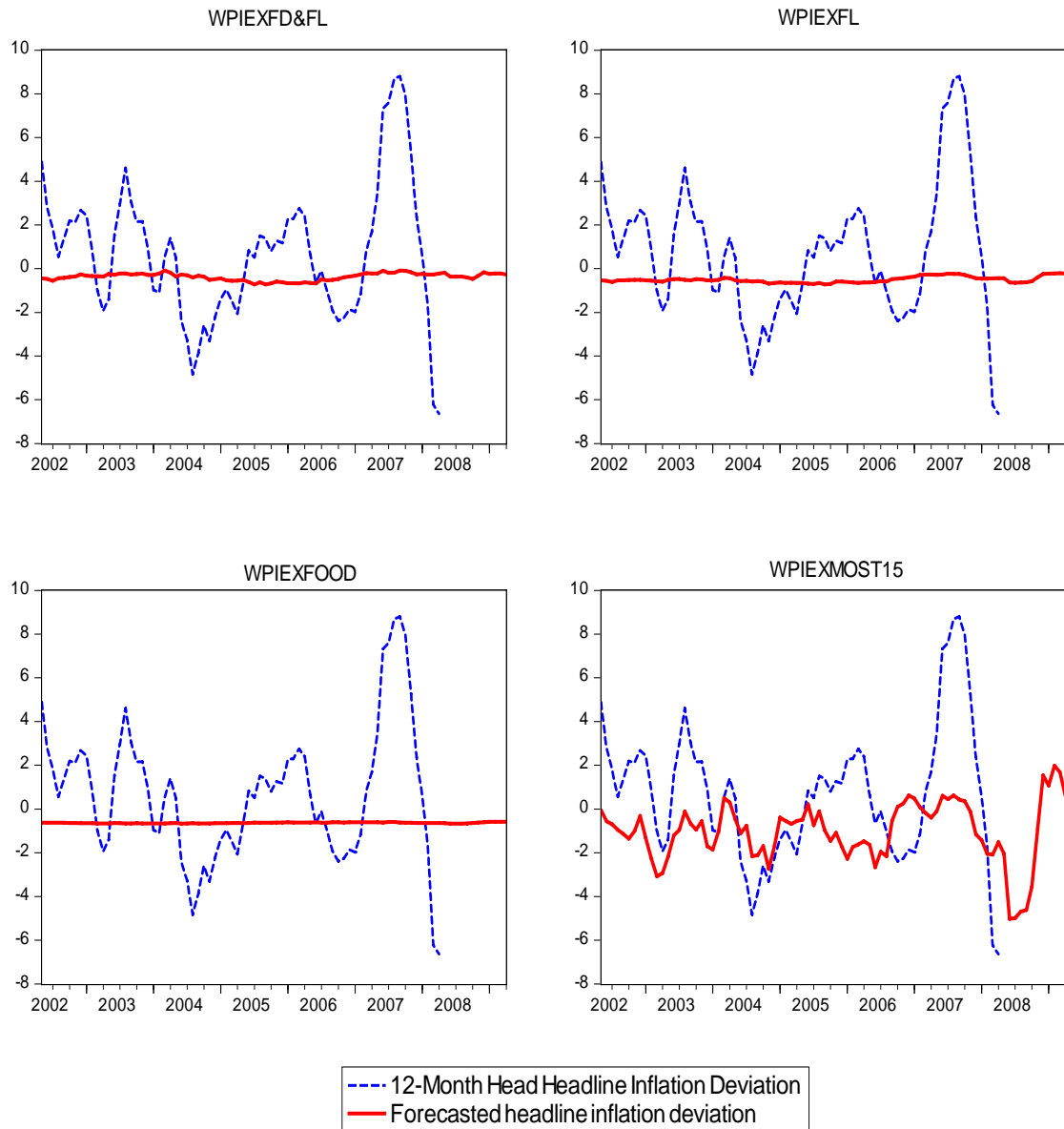


Figure 4.14: Comparison of Forecast

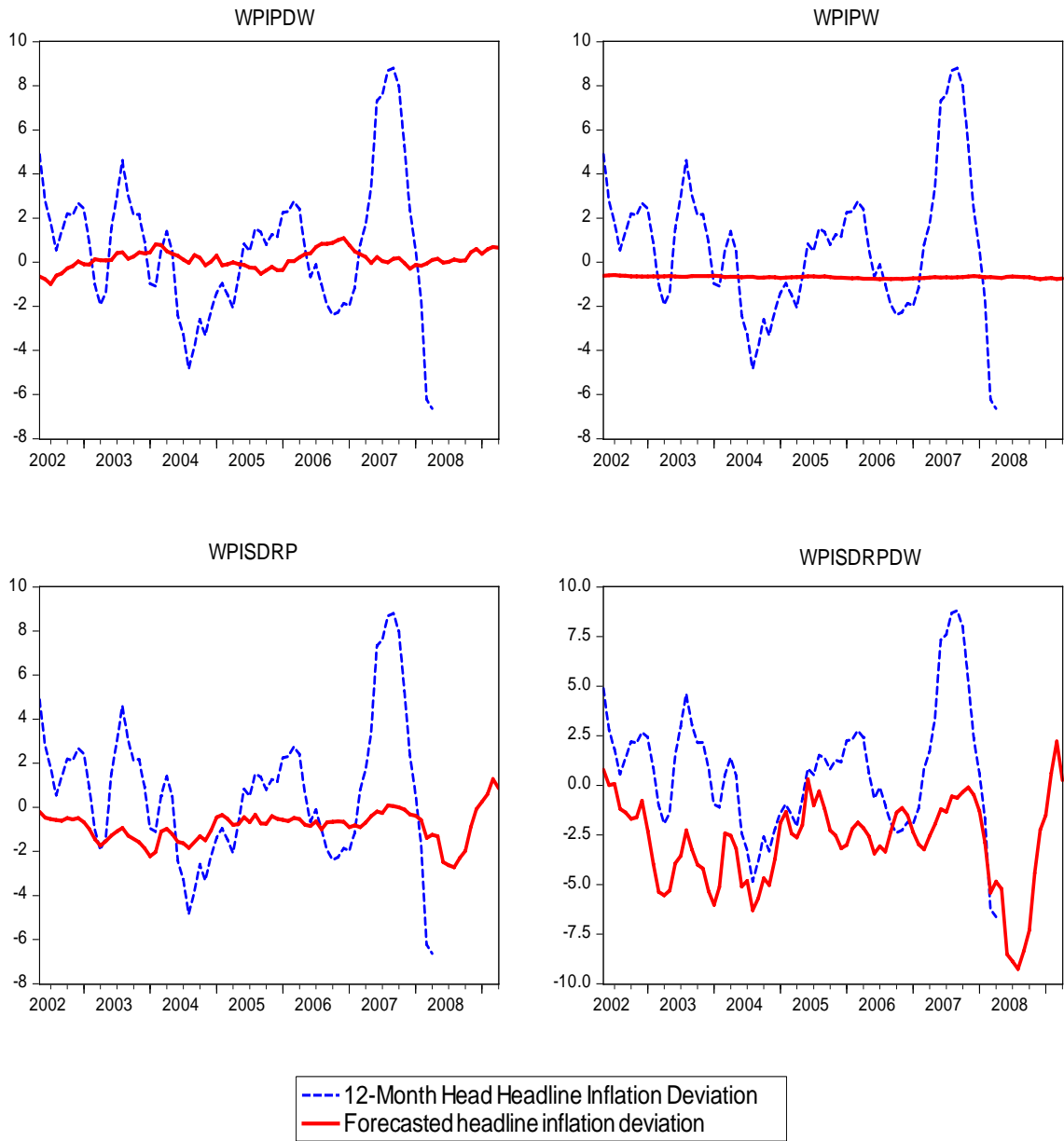


Figure 4.15: Comparison of Forecast

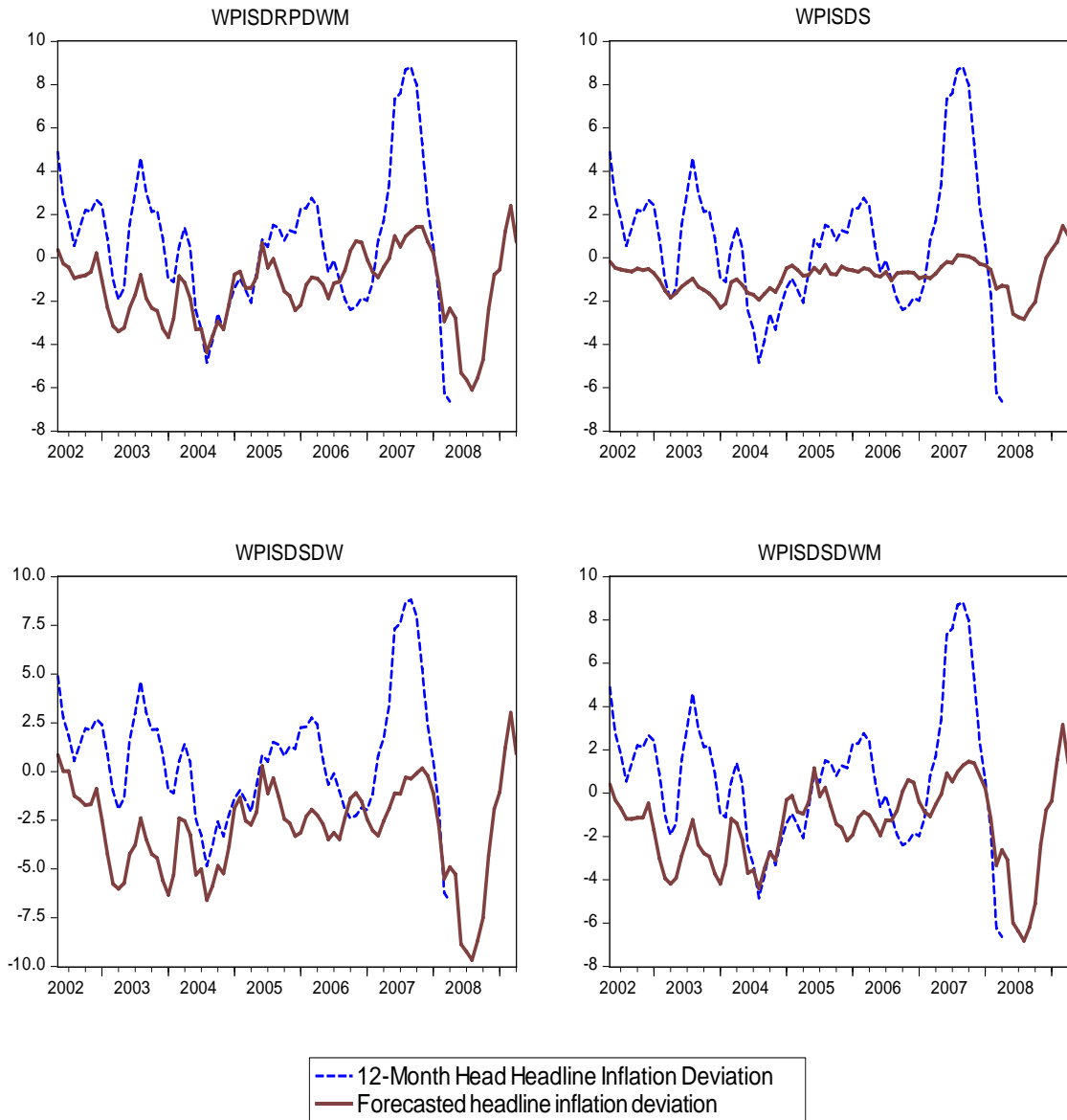
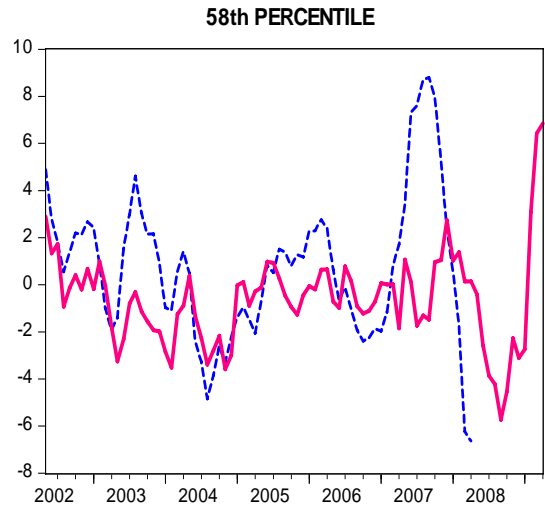
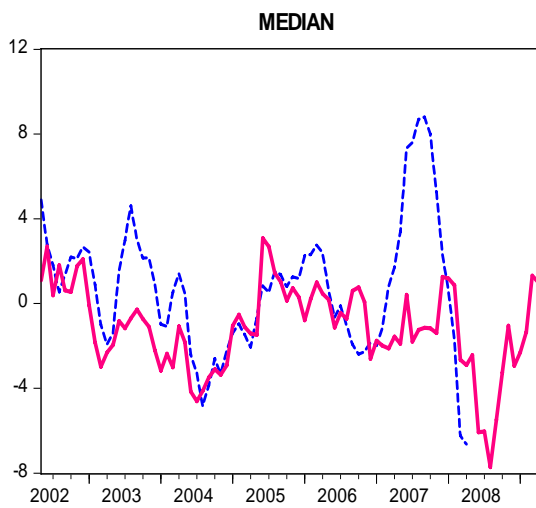
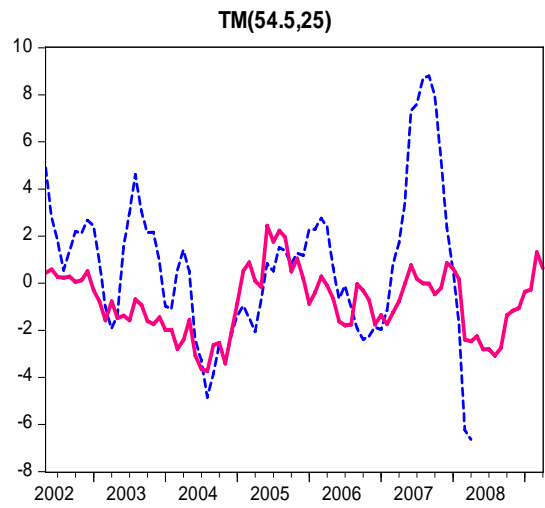
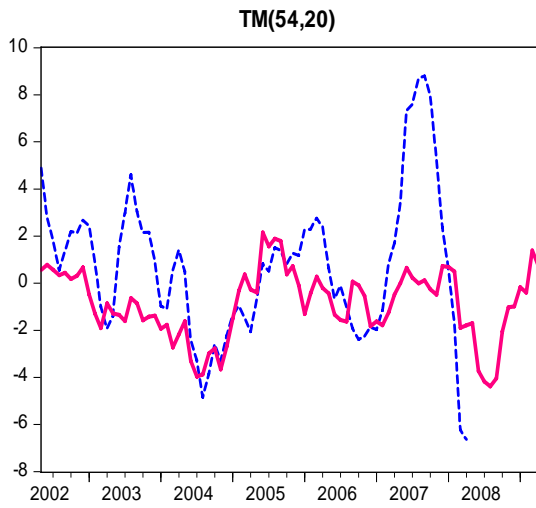


Figure 4.16: Comparison of Forecast



--- 12-Month Head Headline Inflation Deviation
— Forecasted headline inflation deviation

CHAPTER 5

MONETARY POLICY IN INDIA: A STRUCTURAL VARs ANALYSIS

5.1. Introduction

The RBI (1935) sets out the objectives of monetary policy as “maintaining price stability and ensuring adequate flow of credit to the productive sectors of the economy”. However, with progressive liberalization and increasing globalization of the economy, maintaining orderly conditions in the financial markets emerged as an additional policy objective (Mohanty, 2010a). The conduct of monetary policy and its operating procedure has also transformed significantly over time in accordance with pace and changes in financial market and underlying structure of Indian economy.

The monetary policy framework in India between period 1985--98 is considered as “monetary targeting with feedback” policy, recommended by RBI the Chakravarty Committee (1985). Under this approach, M3 is used as a nominal anchor, reserve money as the operating target and bank reserves as the operating instrument (Mohan, 2005). The framework was, however, a flexible one allowing changes in the projected monetary growth consistent with the expected real GDP growth and a tolerable level of inflation (Mohanty, 2010b). In the late 1990’s factors such as increasing financial liberalization followed by financial innovation, large capital inflows, have led to instability in the money demand function in India. As a consequence, it was felt to have multiple policy indicators for policy formulation. Accordingly, there was a shift to multiple indicators approach (MIA) in the late 1990s. In April-1998, the RBI formally announced shifting of its policy framework from monetary targeting to multiple indicator approach (see, Mohanty, 2010a). Under this approach, the RBI considers various economic and financial variables to draw monetary policy perspective.

Although the RBI refers to its current monetary policy framework as the MIA, internationally the more familiar term would perhaps be an implicit nominal anchor approach (Bhattacharya, pp.84, 2006). The RBI regularly provides projections of growth and inflation along with monetary growth, and emphasis is placed on anchoring inflation

expectation in its policy report. The projected variables are however, not mentioned as target, even though the RBI has described it as its commitment to achieve the projected rates. This type of framework is indeed implicit, soft and flexible inflation targeting framework, which is similar to the framework that has been followed by two major central banks viz., the Fed and the ECB. In such monetary policy framework, the central bank usually makes its best assessment of inflation outlook (as RBI does in its current monetary policy framework) and also assess underlying inflation trend particularly core inflation rate while deciding monetary policy³⁵. Since, it is well known that headline inflation is very prone to supply shock, and given monetary transmission lags, a policy response to temporary supply shock to headline inflation may hit growth without reducing shock inflation.

Explicit inflation targeting (IT) is resorted to by the central banks principally to focus on maintaining price stability while formulating its monetary policy. The explicit but flexible IT gives relatively more weight to price stability than that to output growth when it come to judgment between price stability and growth concern. In contrast, the current Indian monetary policy framework indeed has multiple objectives viz., price stability, growth and stable exchange rate³⁶. The last objective is based on the observation of the RBI's frequent intervention in forex market to stabilize exchange rate. With huge capital inflows and outflows, RBI tries to balance between exchange rate stabilization and inflation stabilization, as it seeks to maintain stability in forex market so as to ensure a competitive Indian nominal exchange rate vis-à-vis other currency (particularly US dollar), while simultaneously seeking for low inflation objective³⁷. Thus, a better description of a period (welfare) loss function of RBI current policy is to minimize a weighted average of output, inflation and exchange rate volatilities. The relative weights assigned to these objectives

³⁵ As Blinder and Reis (2005) noted that then Fed's chairman Greenspan had focused on CPI ex-food and fuel core inflation rather than headline CPI inflation in monetary policy formulation. Further, they noted that Greenspan encouraged both the FOMC and the financial markets to focus on core rather than headline inflation in implementing policy.

³⁶ This last objective is better described as maintaining a de facto peg with US dollar. IMF has classified India as de facto exchange rate regimes in 2006 (see IMF, 2006).

³⁷ See, Ajay Shah (2007) article 'Righting the rupee'.

however, depend on economic conditions prevailing at time³⁸. Nevertheless, the RBI has frequently acknowledged in its various reports that the price stability is always the prime concern. In fact, Reddy (2005) has acknowledged price stability as a kind of “informal mandate” for RBI.

Against this background, the aim of the present chapter is to investigate the transmission of monetary policy shocks through changes in interest rates in India since the formal adoption of multiple indicator approach. To examine this, we use a VAR approach with recursive contemporaneous restrictions and identify monetary policy shocks by modeling the reaction function of the RBI and structure of the economy. We then analyse: i) the dynamic responses of the macroeconomic variables to a monetary policy shock with two alternative inflation measures viz., WPI and WPI ex-food and fuel core measures and, ii) operational use and relative role of core inflation measures in monetary policy formulation.

5.2. A Brief Overview of Literature

The literature on the VAR studies of monetary policy can be classified (or reviewed) either on the basis of type of instruments used whose innovations can be called monetary policy shocks, or the effect of these shocks on various parts of the real economy, or on the basis of the assumptions made about the model identification i.e., recursive (the presence or absence of information lags)/non-recursive and closed/open economy or studies that explicitly focus on relative efficacy of various transmission channels of monetary policy.

Among those issues, identification assumption is crucial for identifying monetary policy shocks. Since, the variables are simultaneously determined over time, an identification assumption on contemporaneous causality is required for isolating monetary shocks (Mishra and Mishra, 2006). Two types of identification schemes have been developed in the literature viz., *recursive* and *non-recursive* identification. There are also various alternative *recursive* orderings of variables which were used for isolating monetary shocks. Initially for example, Sims (1980) pioneer of the VAR of monetary policy argued

³⁸ This is implied by RBI various policy speech and documents.

that the policy instrument could be ordered prior to output and prices since contemporaneous measures of output and prices were not available to the monetary authorities when making monetary policy decisions. Bernanke and Blinder (1992) order monetary policy instrument after output and prices assuming that interest rate changes will affect these variables with a lag. The latter identifying assumption is also consistent with the predictions of a number of theories; see for example, Christiano *et al* (1997). The recursive ordering approach is a standard Cholesky decomposition which is done by a lower triangular matrix of coefficients for the contemporaneous variables. There is also large literature on *non-recursive* identification, which is also labeled under structural VAR's (SVAR) for instance, Sims and Zha (1995), and Kim and Roubini (2000). The latter built SVAR for non-U.S. industrial countries (non-US G-7 countries) assuming that monetary authority sets the interest rate after observing the current value of money, exchange rate and world price of oil but not the current values of output, price level, and U.S. federal funds rate.

Apart from recursive or non- recursive and closed or open economy, there is also the issue of so-called 'empirical puzzles', which confronted the researchers in VAR identification. The most widely discussed puzzles in the literature are the price puzzle and exchange rate puzzles³⁹. These puzzles are largely attributed to misspecification of model. A model misspecification often gives biased results which are inconsistent with economic theory. For instance, price puzzle implies that prices initially increase with monetary tightening. The exchange rate puzzle refers to the observed exchange rate initially depreciating when the domestic interest rate rose, while the forward bias puzzle refers to the lack of a subsequent depreciation of the domestic currency in accordance with uncovered interest parity holding (Bredin and O'Reilly, 2004, pp.51). Accordingly, a number of solutions are suggested in the literature to avoid these empirical puzzles. Christiano *et al* (1996), and Sims and Zha (1995) solved the price puzzle with the inclusion of commodity prices in the Fed's information set. Sims (1992) argued that evidence of the price puzzle may be explained by absence of information on future inflation in the information set of the

³⁹ Various empirical puzzles and interpretation are summarized in Kim and Roubini (2000)

central bank while setting up its policy instrument. Cushman and Zha (1997) solved puzzling response of various macro economic variables like exchange rate to interest rate innovations by estimating a structural VAR model for Canadian economy by incorporating the features of small open economy. Similarly, Kim and Roubini (2000) estimated SVAR model for non- US G-7 developed countries and allowed simultaneity between contemporaneous values of the interest rate and nominal exchange rate in model to solve exchange rate puzzles.

To date there has been very little work in Indian context which directly deals with the identification of monetary policy shock in a small open economy and its impact on various macroeconomic variables. We here review monetary policy studies of VAR model in India, in some detail.

Bhattacharyya and Sensarma (2008) examine the effectiveness of alternative monetary policy instruments in transmitting policy signals and its impact on financial market behavior for the post reform data using VAR framework. They used policy instruments such as cash reserve ratio, bank rate and reverse repo rate. They then assessed the impact of those policy instruments on the call money rate, 3-month forward premia, yield on 1-year government securities and BSE Sensex. They found that post-LAF period the reverse repo rate has emerged as most important signalling rate of the RBI. Based on the results, they concluded that the impact of policy instruments was confined to the money, forex and bond markets and not on the stock market, suggesting that short term call money rate are closely related to RBI policy instruments.

RBI (2003) examined monetary transmission mechanism in India using monthly data for the period between 1992M4 to 2002M12 and for period 1981M4 to 1990M6. The study used five variables in recursive-VAR model with the following order: IIP, WPI, non-food credit, broad money and call money rate. The results indicated that a positive shock to broad money leads to higher output, while a positive shock to the call money rate produces the opposite effect. Mishra and Mishra (2006) identified monetary policy shocks in estimating seven variable recursive-VAR models with first differences form of variables. They examined impact of monetary policy shocks on the real side of the economy over the period between 1996M1 to 2005M3, and found that call money rate

shocks gave theoretically consistent results for the major macro economic variables. They suggested that interest rate variables are better in signalling the stance of monetary policy for India than quantity variables (growth rate of reserve money).

Singh and Kalirajan (2007) focused on examining the question; does monetary policy in India work through interest rates in the post-reform period?. They argued that monetary policy in India is undergoing various transformations in the post reform period. The conventional instruments of price and quantity control of monetary transmission are losing their significance. To evaluate the effectiveness of interest rate channel of monetary transmission in the post liberalized Indian economy, they estimated cointegrated vector autoregression model using monthly data over the period between 1993M1 to 2005M3. They further examined the robustness of the behavior of the interest rate (call money rate) vis-à-vis other policy variables, and found that interest rates behave in a reasonably consistent manner. They concluded that interest rates play an important role in the monetary transmission mechanism in the post-reform period in India.

Pandit *et al* (2006) estimated a structural VAR model to examine the bank lending channel in the post-reform period in India. They considered five variables in the model viz., IIP, WPI, commercial paper rate, M3 and, for policy instrument, either CRR or bank rate. Their results suggested that CRR is a better instrument of monetary policy compared to that of bank rate. The results also indicated for the existence of bank lending channel in India. A more recent paper, Aleem (2010) examined three transmission channels of monetary policy in India. He estimated recursive-VAR model using quarterly data from 1996Q4 to 2007Q4. He first estimated a benchmark VAR model with the following order of variables: GDP, WPI and call money rate and a vector of exogenous variables. The call money rate was used as stance of monetary policy. Further, he then augments the benchmark VAR model by including a new variable in each separate model namely, prime lending rate/ bank credit to commercial sector (loan), BSE Sensex-30 and real effective exchange rate which correspond to the bank lending channel, asset price channel and exchange rate channel respectively. The study concluded that banks play an important role in the transmission of monetary policy shocks to the real sector. However, Al-Mashat (2003) found that banks play little role in transmitting monetary policy shocks to the real sector in India. He examined three channels viz., interest rate, bank-lending and exchange

rate channel. He estimated SVAR model using quarterly data from 1981:1 to 2002:4. He also examined the results in two sub-sample, pre-reform and post-reform periods to assess changes in transmission channel. He concluded that the impact of a monetary policy shock on macroeconomic variables is larger after including the exchange rate in the model.

5.3 Methodology

5.3.1 Vector Autoregressions (VARs) Model

This section presents a vector autoregression (VAR) methodology. The VAR model assumes that the economy can be described by the structural form equation. Following literature on standard representation of structural VAR, we express p th order SVAR as⁴⁰:

$$B(L)x_t = \varepsilon_t$$

$$E\varepsilon_t\varepsilon_t' = \Sigma_\varepsilon \tag{5.1}$$

$$E\varepsilon_t\varepsilon_{t+h}' = 0, \quad \forall h \neq 0$$

where x_t is an $n \times 1$ vector of variables, ε_t is an $n \times 1$ vector of structural innovations with zero mean and covariance matrix Σ_ε and $t = -(p-1), \dots, T$. $B(L)$ is the p th order matrix polynomial in the lag operator L , $B(L) = B_0 - B_1L - B_2L^2 - \dots - B_pL^p$. B_0 is a non-singular matrix and is normalized to have ones on the diagonal. The B_0 matrix summarizes the contemporaneous relationships between the variables of the model.

Corresponding to the VAR model given in equation (5.1), is a reduced-form VAR model is given by:

$$A(L)x_t = e_t$$

$$Ee_te_t' = \Sigma_e \tag{5.2}$$

⁴⁰ Note that in actual estimation of VARs model, we include the vector of constants and exogenous variables. For simplicity, we present the model without the vector of constants and exogenous variables.

$$Ee_t e_{t+h}' = 0, \quad \forall h \neq 0$$

where $A(L) = B_0^{-1}B(L) = I - AL - A_0L^2 - \dots - A_pL^p$ and $e_t = B_0^{-1}\varepsilon_t$. The error terms (e_t) are composites of structural shocks (ε_t).

In order to recover the structural parameters from the reduced form model, there must be the same number of parameters in B_0 and Σ_ε as there are in Σ_e , the covariance matrix of the reduced form.

Using Equations (5.1) and (5.2), the variance covariance matrix, Σ_e , can be expressed as:

$$\Sigma_e = B_0 \Sigma_\varepsilon B_0^{-1} \tag{5.3}$$

Maximum likelihood estimation of Σ_ε and B_0 can be obtained through the sample estimation of Σ_e . In Equation (5.3), Σ_e has $n(n+1)/2$ parameters, while the right hand side has $n(n+1)$ free parameters to be estimated. Hence one needs at least $n(n+1)/2$ restrictions. If the n diagonal elements of Σ_ε are set to 1, all that is required is a further $n(n-1)/2$ restrictions on B. There are a number of different methods to recover the parameters of the structural form from the parameters in the reduced form. The most widely used approach is a recursive structure or the Cholesky decomposition (Sims (1980)). Another approach is non-recursive approach in which non-recursive structures are allowed while still giving restrictions only on contemporaneous structural parameters, B_0 ⁴¹ (see Kim and Roubini, 2000).

5.3.2 Variables and Time Series Properties of Data

The VAR models are estimated in levels using monthly data over the period between April-1998 to April-2009. The sample period beginning with April-1998 is considered

⁴¹ This is a short-term contemporaneous restriction on B_0 . The long-run restrictions could also be imposed on $B(L)$.

mainly because since April-1998 the RBI formally announced a new multiple indicator policy framework to conduct monetary policy. The endogenous variables included in the VAR models are industrial production index (y), wholesale price index or core price index (p), nominal exchange rate vis-à-vis the US dollars or nominal effective exchange rate, (e), call money rate (r), and broad money aggregate (M).

We also include federal fund rate and world commodity prices as exogenous variables in the VAR models. The inclusion of these variables as exogenous is motivated on number of counts. We include these variables in the model in order to take into account an external constraint and to control for fluctuations in world inflation since; monetary policy decisions in emerging economies like India are influenced by the world's major central banks such as the US Fed. Figure 5.1 shows the movement between call money rate and federal fund rate over the sample period. The Figure shows similar movements between the two rates, suggesting that monetary policy in India is constrained by external Fed's monetary policy. Since, one of the objectives of RBI current monetary policy is to stabilize exchange rate, any abrupt changes in Indian rupee vis-à-vis foreign currency especially US dollar would produce undesirable effects on foreign trade and also create a fear of capital out flow⁴². Hence, we need to control for changes in the domestic interest rate that are responses to changes in the Fed interest rate (i.e., to include Fed's fund rate as exogenous variables in the model). Further, the proper identification of monetary policy shock in emerging economies like India is needed to include the world constraint in model. Any misspecification of model may otherwise give some puzzling results which are contrary to what the theory stipulates.

Another issue that needs to be discussed is the appropriate variable for policy instrument. Since, the analysis of effectiveness of monetary policy in VAR framework is sensitive to the choice of variable used to capture the monetary policy stance, we use short term call money rate as monetary policy stance. Note that RBI (2005) emphasized in its report that “a gradual deregulation of financial markets and a move towards indirect instruments of

⁴² This hypothesis is due to an influential NBER paper titled ‘fear of floating’ by Calvo & Reinhart (2000)

monetary management, short-term interest rates have emerged as instruments of conveying the monetary policy stance” (pp.171). RBI conducts its monetary operation through indirect instrument with the introduction of Liquidity Adjustment Facility (LAF) scheme and the Market Stabilization Scheme (MSS)⁴³. The LAF scheme commenced from June 5, 2000 with the objective of bringing financial stability and creating a de facto corridor for the short-term interest rate through daily repo and reverse repo auctions. The liquidity is absorbed from market at the reverse repo rate (floor) and injected in the market at the repo rate (ceiling). A change in these policy instruments affects the short-term interest rates. Following the changes in short-term interest rates, an entire range of monetary and financial variables is then affected (see Bhattacharyya and Sensarma, 2008). Consequently, the changes in the monetary and financial variables affect the aggregate demand. Various other alternative monetary policy instrument (or operating instrument) such as bank rate⁴⁴ and CRR are also positively and closely correlated with call money rate as found by Bhattacharyya and Sensarma (2008). Hence, it is not surprising that the call money rate has emerged as an informal operating target instrument in the current framework of monetary policy as oppose to quantity operating procedure of monetary policy during the period 1985-95, where reserve money was used as operating target. Previous empirical studies, for instance Kalirajan (2007) and Aleem (2010), have also used the call money rate to capture the monetary policy stance for post-reform period data. Turning to first para of the section, we transform all variables in natural logs and also seasonally adjusted using ARIMA X12 procedures, with the exception of the call rate, which is already in levels and not seasonally adjusted. Figure 5.2 shows the endogenous variables used for the analysis. Detail on data sources are given in Appendix I. Before going to VAR estimation, we performed the Augmented Dicky Fuller (ADF) test and Phillips Perron (PP) for the presence of unit roots in the series. The results of PP unit root

⁴³ Beside open market operation (OMO) sales and LAF, the market stabilisation scheme (MSS) is the additional instruments of sterilization, which was introduced in April 2004, in order to manage large and mounting capital inflows in Indian economy. Under this scheme, “short term government securities were issued but the amount remained impounded in the Reserve Bank’s balance sheet for sterilisation purposes” (Mohanty 2010a, pp.6).

⁴⁴ The bank rate is now almost dismantled from practice; it is now mainly referred for long term lending rate.

tests (Table 5.2) suggest that except call money rate all series are integrated of order one in levels, i.e., I (1), and I (0) in differences. Using standard cointegration tests there is evidence of at least two cointegrating relationships. As standard in VAR analysis of monetary policy, and without going into discussion on the issue⁴⁵, we estimate all VAR model in level form data. Doing so, we allow explicitly cointegration relationships in the data. We estimate all VARs with constant and with endogenous and exogenous variables as defined above. The lag length for the VARs is decided on the basis of results of the sequential modified likelihood ratio (LR) tests⁴⁶, which turns out lag four.

5.4 Identifications Structure and Results of Monetary Policy Effect

We identify monetary policy shocks in recursive structure of VARs by modelling current policy reaction function of the RBI. Following the literature, we start by including the headline WPI index in the VAR analysis, and then we replace headline WPI index with WPI excluding food and fuel core measure. We consider these VAR models as the benchmark models. We proceed examining the effectiveness and robustness of the results from benchmark recursive identification model vis-à-vis alternative identification of VAR model. We then generate results estimating SVAR assuming a scenario where RBI sets the interest rate after looking at only core prices, a case similar to core inflation (price level) targeting framework.

We use standard approach of identification scheme that imposes a recursive structure of the VAR, with the following ordering of variables: output (y), WPI prices (p) and nominal effective exchange rate (e), call money rate (r), money supply (M) in that order. This ordering of the variables implies that B_0 is given by

⁴⁵ Given problem of degrees of freedom in short sample at hand and also considering that the short sample is not suitable for explicit analysis of the long-run behavior of the economy, we do not consider use of SVECM. For further justification and details on the issue one can refer Kim and Roubini (2000) and Favero (2004).

⁴⁶ It is important to decide appropriate lag length (p) while estimating VARs models. Since, if auto correlation is present the estimated coefficient will be inconsistent. We prefer LR test criterion as the chosen lag length by LR is confirmed no-auto correlation according to LM test.

$$B_0 x_t = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ B_{21} & 1 & 0 & 0 & 0 \\ B_{31} & B_{32} & 1 & 0 & 0 \\ B_{41} & B_{42} & B_{43} & 1 & 0 \\ B_{51} & B_{52} & B_{53} & B_{53} & 1 \end{bmatrix} \begin{bmatrix} y \\ p \\ e \\ r \\ M \end{bmatrix}$$

Here, y , p and e form the RBI's information set variables (i.e., policy target variables) and (r) is monetary policy instrument. Specifically, we assume that the RBI modulates the call money rate after observing the current values of prices, output and nominal exchange rate. This assumption is consistent with the multiple indicator approach currently followed by the RBI. The information set also reflects a period loss function of the central bank that minimizes a weighted average of output, inflation and exchange rate volatilities.

The above structure imposes contemporaneous restriction among variables such that innovations to the monetary policy instrument (call money rate) have no immediate effect on output, prices and nominal exchange rate but with a lag. M is placed after the monetary policy instrument, which is assumed to react to monetary policy instrument contemporaneously. The equation M is regarded as the open economy money demand function. The equation r would give open economy reaction function (feedback rule) of central bank to changes in output, prices and nominal exchange rate shocks.

Figure 5.3 presents the impulse responses of the variables estimated by the benchmark VAR model to positive one-standard-deviation innovation to the call money rate (i.e., a contractionary monetary policy shock). The dashed lines denote a 95% confidence interval for the impulse response functions. The Figure shows that the impulse responses of the major economic variables give theoretically consistent results to a contractionary monetary policy shock. There is decline in output and prices following a positive monetary shock. The dynamic impulse responses also show that the prices start declining following after the decline in output and take three months to fall below the baseline level. This suggests that monetary policy would first affect output and subsequently prices. This provides evidence for non-neutrality short-run effect of monetary policy in India which is

consistent with the prophecy of Keynesian models (theory/paradigm)⁴⁷. The maximum decline in prices can be seen in the seventh months, which is indicative of monetary policy lag of transmission mechanism in India. We should note that the price puzzle, which emerged when we estimated the benchmark model without exogenous variables, (which is depicted in Figure 5.4), disappears when we included the exogenous variables in the benchmark model. The response of nominal exchange rate to shock is also in line with the economic theory. A positive innovation to call money interest rate leads to an initial rise (appreciation) in the nominal effective exchange rate (NEER) and subsequently decline and fall below baseline level, which is in accordance with uncovered interest parity hypothesis. Thus, the benchmark identification VAR model produces theoretically consistent results, which precisely capture the changing monetary policy dynamics. Figure 5.5 presents the estimated monetary policy shocks (call money rate shocks) from the model and call money rate. We find that the call money rate innovations closely follow the actual call money rate.

We also use nominal exchange rate expressed in units of rupees (domestic currency) for one unit of U.S. dollars, “₹/\$”, in the benchmark model instead of nominal effective exchange rate (NEER). The results are shown in Figure 5.6. The estimated impulse responses gave theoretically similar results to those of nominal effective exchange rate in the benchmark model⁴⁸.

Table 5.3 presents the Forecast Error Variance Decompositions (FEVD) for the WPI benchmark model. The result shows that a shock to the call money rate accounts for about 8 percent of the fluctuations in output at a forecasting horizon of one year. While, the results for nominal effective exchange rate (NEER) indicate that the shocks to call money rate account for a very small percentage (about 2-3) percent of the fluctuations in NEER, the results of FEVD for WPI prices show that the variation in WPI prices are explained more by money supply and NEER shock and very less by output shock and call money

⁴⁷ Some previous studies such as Aleem (2010) also found a short-run output fall and subsequently prices fall.

⁴⁸ Note that here a decline in impulse response of ₹/\$ indicate *appreciation* of Indian rupee vis-à-vis US dollars.

rate shock. An interesting point to be noted here is that money supply is playing an important secondary role in explaining movements in inflation as it explains almost 18% variation in WPI prices at a forecasting horizon of two years. Variations in call money rate are largely explained by its own shocks. It is relatively affected more by NEER shock than output and WPI price shocks, as WPI price shocks explain only a negligible percentage of around 3% of volatility in call money rate at forecasting horizon of one to two years.

Next, we consider use of WPI ex-food and fuel core measure in the benchmark model estimation (henceforth core measure/core prices). Given that most central banks use core measures as useful information variables while formulating monetary policy, we consider that it is imperative to examine WPI ex-food and fuel core measure as an information variable in the RBI reaction function instead of WPI measure⁴⁹. Accordingly, we estimate benchmark VAR model by replacing WPI ex-food and fuel measure in place of WPI measure.

Impulse responses from the benchmark VAR using core measure are shown in Figure 5.7. The Figure shows the impulse responses of major macro variables to monetary policy shock are similar to the results of WPI analysis. However, we find one major difference that unlike WPI prices, the response of core prices declined swiftly and immediately following a positive monetary policy shock. Further, the decline in the core price level is persistent over the 24 months horizon. This gives some evidence that monetary policy would work more effectively on core prices, which by definition represents trend prices, reflecting the aggregate demand side pressure in the economy. It is important to note that when we estimate benchmark VAR for core prices without including commodity prices as exogenous variable, the impulse responses gave theoretically consistent results without generating price puzzle. As noted before, Christiano *et al* (1996) solved the price puzzle in a recursive system by adding commodity prices as a proxy variable for inflation expectation in the model. This suggests that (the inclusion of) core prices in the RBI information set (may) act as an indicator of inflation expectation.

⁴⁹ We also use some other core measures in the estimation, however, as our analysis only explain later why we prepare to report only WPI ex-food and fuel core measure.

The results from the variance decomposition for core price model (Table 5.4) are also consistent with the impulse response analysis, and repeat the results of the WPI analysis. However, two results are noteworthy to mention. First, core prices are affected more by output shocks (economic activity) and less by nominal effective exchange rate (NEER) shocks. The NEER shocks explain around 4 % of volatility in core prices at a forecasting horizon of one year, suggesting a lower exchange rate pass-through; this is because of the fact that the volatile fuel and food prices are eliminated from the price index. However, the contribution of NEER shock has increased steadily and become second important shock in explaining variation in core prices at horizon of two years, indicating that imported prices, particularly oil and commodity prices, are indeed persistent and become generalized over two year horizon⁵⁰. Another difference is that the contribution of call money rate shock is relatively more pronounced than money supply shock in explaining variation in core prices. Second, unlike the case of headline WPI prices, the variations in call money rate has now been explained relatively more by core prices while the contribution of other shock to call money rate remain same as in the case of WPI model over the one to two year horizon. If we interpret the variations in the call money rate as variations in the monetary policy instrument, this result suggests that changes in monetary instruments are relatively reacted (affected) more to (by) shock to core prices than to a shock to WPI prices⁵¹.

Finally, we note the results of impulse responses for both WPI and core prices to a positive shock to money supply, which give some evidence regarding efficacy of transmission channel and type of price measure to be used for policy decision. Figure 5.8 shows that in case of WPI model, a positive shock to the money supply increases WPI prices immediately and this effect persists, while, in the case of core price model, a shock to money supply has a small transmission effect on core prices compared to the case of headline WPI.

⁵⁰ Note that this result reflects the observed fact that high inflation episodes in India have largely driven by food and fuel components and which are at extent imported in nature. Further, during the sample period, high inflation episodes have frequently witnessed a high persistency due to the persistency in the prices of primary food and fuel components prices.

⁵¹ Since, in this exercise monetary shocks are identified by call money rate shocks, this result may indicate that slightly more importance has been given to core price fluctuations than to WPI

Thus, the results suggest that call money rate shock is stronger for core prices, while a transmission of money supply shock is stronger for WPI prices compared to the case of core prices. More specifically, this result suggests that for core prices where the interest rate channel is stronger, ‘Taylor-type’ rule is more applicable, and for WPI prices ‘McCallum-type’ rule that target money supply would be more appropriate. However, as noted in the introduction, the RBI has formally shifted its operating procedure of monetary policy from monetary targeting to multiple indicator approach in late 1990’s. The RBI is greatly relying on indirect instrument (price instrument) and operating its monetary management through interest rate channel. Therefore, under the present framework of rule based policy, core inflation measures are seem to be more appropriate measures.

5.4.1 Robustness Analysis

We examine robustness of benchmark VAR identification with alternative identification schemes. First, following Kim and Roubini (2000), we ordered nominal exchange rate after call money rate assuming that it is a financial variable and is affected by all the other variables in the system⁵². The results show that the estimated impulse responses give price puzzle and exchange rate puzzle. (see, Figure 5.9). Thus the ordering of the exchange rate variable before the call rate in benchmark model can be further justified. Since, on the ground that in emerging economies like India, central bankers are concerned about variation in exchange rate and take quick actions to stabilize volatility in exchange rates and bring it at unannounced desired path.

Following Kim and Roubini (2000), and Bredin and O'Reilly (2004), we also consider possible simultaneity between interest rate and exchange rate shocks in Indian context assuming that with capital mobility, interest rate changes might have an immediate effect on the exchange rate and exchange rate shocks are likely to affect the setting of interest rates. Additionally, we consider the shock to output does not have an immediate effect on

⁵² Kubo (2008) pointed out that if one is solely interested in the effect of a monetary policy shock, the ordering of the variables before the monetary policy instrument is not important, since the block recursive assumption ensures the same estimation. Hence, we do not consider interchanging the position of prices, output and exchange rate before the call money rate.

the setting interest rate⁵³. More specifically, we modify (impose) the following contemporaneous restrictions on B_0 :

$$B_0 x_t = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ B_{21} & 1 & 0 & 0 & 0 \\ B_{31} & B_{32} & 1 & B_{34} & 0 \\ 0 & B_{42} & B_{43} & 1 & 0 \\ B_{51} & B_{52} & B_{53} & B_{54} & 1 \end{bmatrix} \begin{bmatrix} y \\ p \\ e \\ r \\ M \end{bmatrix}$$

The above contemporaneous structure assumes that the central bank looks after only exchange rate and prices while setting interest rate and assume a simultaneity between call money interest rate and nominal exchange rate shocks, expressed as units of rupees for one unit of U.S. dollars (₹'/\$). The results are shown in Figure 5.10. As Figure shows the impulse responses are not sensible⁵⁴. A positive shock to call money rate leads to rise in price level and the depreciation of the exchange rate, generating results that counter to the predictions of economic theory and gives rise to price puzzle and exchange rate puzzle⁵⁵. This suggests that the reaction function for monetary authority (RBI) is misspecified. Hence, the benchmark identification VAR model turned out robust, which properly specified policy reaction function of RBI during the sample period.

5.4.2 WPI Ex-Food and Fuel Targeting Case (Alternative Non-Recursive Model)

⁵³ This is because of the assumptions that the information on nominal exchange rate and prices are available with higher frequency compared to the same for IIP during sample period.

⁵⁴ These findings further suggest that unlike in case of developed countries, a recursive identification scheme with respect to the interest rate and the exchange rate are appropriate for emerging and a small open economy like India. For instance, Kim and Roubini (2000) and Bredin and O'Reilly (2004), the former authors allowed contemporaneous interaction between domestic interest rate and the exchange rate vis-à-vis the US dollar for non US G-7 developed economies while the later author allowed contemporaneous interaction between domestic interest rate and the exchange rate vis-à-vis German mark and England sterling for Ireland case.

⁵⁵ These results are also found same for WPI ex-food and fuel core price measure.

We have seen that the benchmark model for both WPI prices and core prices gave theoretically consistent results. This allowed us to use the benchmark specification to build a scenario in the benchmark VAR model, where we assume that the RBI sets its policy instrument only by looking at WPI ex-food and fuel prices. Specifically, we examine whether the RBI is indeed giving more weight on price stabilization than to other policy objectives in its policy reaction function. This assumption is like a case of inflation targeting (anchoring). Thus, we impose a non-recursive structure on contemporaneous matrix B_0 in the benchmark VAR model as:

$$B_0 x_t = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ B_{21} & 1 & 0 & 0 & 0 \\ B_{31} & B_{32} & 1 & 0 & 0 \\ 0 & B_{42} & 0 & 1 & 0 \\ B_{51} & B_{52} & B_{53} & B_{53} & 1 \end{bmatrix} \begin{bmatrix} y \\ p \\ e \\ r \\ M \end{bmatrix}$$

We impose restrictions only on the contemporaneous coefficients and not any restrictions on the lagged parameters of the monetary reaction function. Hence, there are still possible monetary policy reactions to the other variables with a lag. We conduct the likelihood ratio test of over-identifying restrictions, which suggest that the null of over-identification restrictions are not rejected at any conventional significance.

Figure 5.11 and Table 5.5 present the results of impulse responses and variance decomposition for WPI ex-food and fuel targeting case. The results indicate that the responses of macro variables to a positive one standard deviation shock to call money rate is not very different from the results of impulse responses from the benchmark recursive core price model. This may suggest that although RBI has not explicitly stated, but in its policy reaction function, price stabilization gets more weight than nominal exchange rate and output⁵⁶.

⁵⁶ It is pointed out, however, that even in countries whose central bank seeks to minimize a weighted average of output and inflation volatilities, the optimal policy can be described in terms of pure inflation targeting in the long run (Svensson, 1997).

We make some observation on the use of WPI ex-food and fuel core measure in the model and its results, to support overall conclusion drawn from VAR's estimation, which are follows:

First, we consider WPI ex-food and fuel core measure as an alternative measure for WPI measure in the reaction function equation (feedback rule) of VAR model mainly because the RBI discusses these type of core measures in its policy reports⁵⁷. The implicit use of such measure in RBI policy deliberation was further noted in Y.V. Reddy's (1999) policy speech that ".....dilemma arises when inflation rate accelerates because of supply shocks, which are expected to be temporary. This, for example, was the situation last year when, until October, inflation was accelerating due to lower availability of a few primary commodities. The Reserve Bank at that time chose not to tighten monetary policy in the expectation that the price risk would reverse itself later in the year when agricultural supplies improve. In retrospect, this judgement turned out to be correct" (pp, 7). We use other type of core measures such as standard deviation based core measure or trimmed mean core measures in place of WPI ex-food and fuel core measure in the benchmark VAR model. The estimated impulse responses for these alternative core prices however, gave 'price puzzle'⁵⁸. This is because the relationship between monetary policy and inflation measures in the sample data is sensitive to type of inflation measures used in the monetary policy decisions. Hence, we can say that the RBI has considered only some type of WPI ex-food and fuel measures in its policy deliberation during the sample period⁵⁹.

Second, as noted in the introduction that the RBI policy documents extensively discusses anchoring inflation expectation. There was no survey data or regular survey on household

⁵⁷ There is a single study at the RBI (occasional paper by Samanta, 1999) that calculated four WPI ex-food and fuel type of core measures and suggested the use of those measures for policy formulation. We should also note that RBI analyses the sectoral inflation development such as food group, fuel group, and other major commodities and its impact on overall inflation development in its quarterly report in the being 'price section', in view of short term sectoral inflation development primarily driven by the dynamics of the sectoral specific market.

⁵⁸ We therefore do not report these results.

⁵⁹ However, it should be noted that we found in the previous chapter that WPI ex-food and fuel type core measures has not preformed well on certain prespecified criteria of useful core measure. Therefore, we argued there that the RBI should consider information on other type of core mesures along with conventional ex-food and fuel measures in the policy deliberation.

inflation expectation at RBI until 2009-only recently RBI has begun to publish household inflation expectation survey in its policy reports.⁶⁰ This may suggest that the WPI ex-food and fuel type measures may have been used as proxies for *underlying* inflation expectation in the economy⁶¹. Third, high inflation episodes in India have been generated from mainly supply side factors such as high global oil and food prices, which are temporary in nature and likely to be reversed to initial levels⁶². Then, given monetary transmission lag, it has been argued that any changes in relative prices, on account of supply shocks, monetary policy need not respond. A policy response at time 't' to temporary supply shock to inflation may hit growth without reducing shock inflation and it affects inflation only at time 't+n' gradually when inflation in fact reverses to its trend level. Fourth, Mehra and Sawhney (2010) and Blinder and Reis (2005) have showed that the U.S Federal Reserves Bank in the Greenspan era had focused on core measure rather than headline measure in the implementation of monetary policy. As we noted previously that RBI implicitly follows Fed's policy framework (see Figure 5.1). Therefore, RBI may also have considered information on WPI ex-food and fuel type core measures in monetary policy deliberations.

Taking together the results of VAR's and observation made above, we conclude that the RBI informally targets some form of WPI excluding food and fuel core prices and has been considering information on these core measures instead of WPI measure when it comes to adjust policy instruments from time to time. At the same time it announces and

⁶⁰ RBI Bulletin May-2010 issue gives detailed technical methodology on inflation expectations of households survey along with the results from September 2008 to March 2010.

⁶¹ Reddy (1999) had suggested using a weighted average inflation rate with a distributed lag such as a five year moving average of the inflation rates as an indicator for inflation expectation. Further, he read core inflation as "the permanent component [is] often called the 'underlying rate of inflation or the 'core rate of inflation. It is not the current rate of inflation, comprising transient components, but the future underlying rate of inflation (i.e., *inflation expectation*), which should be the concern of monetary policy." (pp.7).

Indeed, there are two ways by which Central Banks generally gauge inflation expectations: one is based on survey approach that use survey data on households, professional forecasters and businesses and second that use financial market instrument such as Inflation Protected Securities (IPS) and Inflation linked Swaps to measure inflation expectation.

⁶² This has been documented and analyzed in the various RBI policy reports.

maintains price stability in terms of WPI measure viewing them as medium term objective.

5.5 Concluding Remarks

This chapter provided a VAR analysis of monetary policy in India over a period that covers the term after the RBI adopted a multiple indicator approach. We identify monetary policy shocks in a recursive structure of VARs by modelling current policy reaction function of the RBI and structure of economy. In this recursive-VAR approach, we assume that RBI modulates the call money rate after observing the current values of prices, output and nominal exchange rate. This assumption is consistent with the multiple indicator approach currently followed by the RBI. Considering that the proper identification of monetary policy shock in emerging economies like India is needed to include the world constraint in model, we included exogenous variables namely, federal fund rate and world commodity prices in the model. We then examined the dynamic responses of the macroeconomic variables to a call money rate shocks with WPI and WPI ex-food and fuel core measure in separate benchmark VAR model estimation. Overall, the results for both WPI and core prices model suggested that the responses of macro variables to call money rate shock were qualitatively consistent with the predictions of theories. Thus, the results can be considered as a good approximation of the monetary policy dynamics in a new policy framework of RBI. However, we found one major difference that unlike in the case of WPI model, the response of core prices declined swiftly and immediately following a positive call money interest rate shock. Further, the decline in the price level was persistent over the 24 months horizon. This gives some evidence that monetary policy would work more effectively on core prices, which by definition represents trend prices, reflecting aggregate demand side pressure in the economy. We further examined results of impulse responses to a positive shock to money supply. The results suggested that the transmission of money supply shock were stronger for WPI prices compared to the case of core prices, while interest rate channel was stronger for core prices. Given that RBI greatly operates its monetary management through interest rate channel under current policy framework, core inflation measures are thus seen to be more appropriate measures.

Subsequently, we examined robustness of the benchmark VAR results with alternative ordering and non-recursive identification schemes, which were in the spirit of Kim and Roubini (2000), and Bredin and O'Reilly (2004). The results indicated that the impulse responses were not sensible as there was price puzzle and exchange rate puzzle. We then generated a scenario in the benchmark recursive VAR model, where we assumed that RBI sets its policy instrument only looking after the core prices. Based on those results, we concluded that although RBI may not have explicitly stated about the inflation targeting but it has been implicitly targeting WPI ex-food and fuel type core measures and considering information on these core measures when it comes to adjust policy instruments from time to time. Notwithstanding this, given empirical disadvantages associated with conventional exclusion type core measures as found in previous chapter, and considering that “each measure of core inflation can provide some particular insight into how inflation is evolving”, we conclude that the RBI should consider other useful core measures to generate overall outlook on dynamics of inflation development which can be then fed into the forward looking monetary policy formation.

Table 5.1: ADF Unit Root Tests: Variables In Level and First Differences

Variables	p-value	Lag	Max Lag	Results
WPI	0.94	1	12	I(1)
DWPI	0.00	2	12	I(0)
WPI Ex-Food & Fuel	0.99	1	12	I(1)
DWPI Ex-Food & Fuel	0.00	2	12	I(0)
WPI Ex-fuel	1.00	1	12	I(1)
DWPI Ex-Fuel	0.00	1	12	I(0)
Output	0.97	1	12	I(1)
DOutput	0.39	10	12	I(1)
Money supply	1.00	0	12	I(1)
DMoney supply	0.36	11	12	I(1)
NEER	0.40	0	12	I(1)
DNEER	0.09	9	12	I(1)
Exchange rate versus US dollar	0.27	1	12	I(1)
DExchange rate versus US dollar	0.02	4	12	I(0)
Call money rate	0.24	4	12	I(1)
D Call money rate	0.00	0	12	I(0)

Table 5.2: Phillips-Perron Test Results (PP): Variables in Level and First Differences

Variables	p-value	Bandwidth	Results
WPI	0.91	5	I(1)
DWPI	0.00	1	I(0)
WPI Ex-Food & Fuel	0.99	6	I(1)
DWPI Ex-Food & Fuel	0.00	4	I(0)
WPI Ex-fuel	1.00	5	I(1)
DWPI Ex-Fuel	0.00	3	I(0)
Output	0.97	6	I(1)
DOutput	0.00	1	I(0)
Money supply	1.00	4	I(1)
DMoney supply	0.00	2	I(0)
NEER	0.25	3	I(1)
DNEER	0.00	1	I(0)
Exchange rate versus US dollar	0.25	6	I(1)
DExchange rate versus US dollar	0.00	1	I(0)
Call money rate	0.00	5	I(0)
DCall money rate	0.00	54	I(0)

Notes: D denote difference operator

The lag has been chosen on the basis of modified Schwartz information criterion

Table 5.3: Forecast Error Variance Decomposition in Benchmark Model with WPI

Variance Decomposition of Output (y)					
Period	Output	WPI	NEER	Call rate	Money supply
1	100.00	0.00	0.00	0.00	0.00
3	91.69	0.26	5.27	2.72	0.05
6	81.19	4.40	7.77	6.08	0.56
12	60.54	5.35	23.39	8.63	2.10
15	53.68	4.87	30.12	8.03	3.30
18	49.03	4.46	34.43	7.43	4.65
24	44.16	4.00	37.69	6.68	7.47
Variance Decomposition of WPI (p)					
Period	Output	WPI	NEER	Call rate	Money supply
1	0.11	99.89	0.00	0.00	0.00
3	0.25	97.52	1.62	0.00	0.61
6	1.20	90.02	2.70	1.61	4.49
12	2.08	77.08	7.61	2.62	10.61
15	2.12	74.08	8.36	2.55	12.89
18	2.09	72.23	8.35	2.55	14.78
24	3.04	69.07	8.01	2.46	17.41
Variance Decomposition of NEER (e)					
Period	Output	WPI	NEER	Call rate	Money supply
1	0.67	5.34	93.99	0.00	0.00
3	3.44	2.68	92.22	1.32	0.33
6	4.25	3.24	91.18	1.00	0.34
12	9.66	3.80	84.25	1.53	0.76
15	11.22	4.11	81.63	2.17	0.86
18	12.02	4.29	80.08	2.71	0.89
24	12.21	4.31	79.43	3.17	0.88
Variance Decomposition of Call money rate (r)					
Period	Output	WPI	NEER	Call rate	Money supply
1	0.52	0.00	1.37	98.11	0.00
3	1.95	0.44	8.06	88.91	0.65
6	2.90	2.03	8.87	85.38	0.82
12	3.55	2.67	10.02	82.84	0.92
15	3.86	3.04	10.13	81.96	1.01
18	4.02	3.17	10.11	81.61	1.08
24	4.08	3.21	10.16	81.40	1.15
Variance Decomposition of Money supply (M)					
Period	Output	WPI	NEER	Call rate	Money supply
1	0.25	0.33	2.59	1.13	95.69
3	0.70	0.70	5.26	1.05	92.28
6	6.79	2.16	5.40	0.75	84.89
12	21.86	3.33	3.07	0.88	70.85
15	27.62	3.98	2.59	1.62	64.19
18	31.46	4.53	2.77	2.46	58.79
24	34.42	4.98	5.35	3.67	51.58

Table 5.4: Variance Decomposition for Benchmark Model with WPI ex-food and fuel (Core prices)

Variance Decomposition of Output (y)					
Period	Output	Core	NEER	Call rate	Money supply
1	100	0.00	0.00	0.00	0.00
3	93.1	0.33	3.94	2.56	0.07
6	86.05	2.82	5.4	5.41	0.32
12	66.17	2.64	20.3	9.01	1.88
15	57.98	2.7	27.35	8.55	3.41
18	52.57	3.65	30.88	7.81	5.08
24	47.46	6.1	31.51	7.02	7.9
Variance Decomposition of Core prices (p)					
Period	Output	Core	NEER	Call rate	Money supply
1	0.23	99.77	0.00	0.00	0.00
3	0.99	97.66	0.92	0.36	0.07
6	5.52	90.6	1.18	2.36	0.34
12	20.54	69.06	4.47	5.68	0.24
15	21.89	61.63	9.03	7.23	0.23
18	20.53	56.09	15.04	8.00	0.34
24	17.84	49.55	23.92	7.55	1.14
Variance Decomposition of NEER (e)					
Period	Output	Core	NEER	Call rate	Money supply
1	0.65	8.89	90.47	0.00	0.00
3	3.75	10.37	83.77	1.52	0.6
6	6.89	10.52	80.54	1.41	0.64
12	16.52	15.97	65.01	1.45	1.05
15	17.71	18.46	60.85	1.91	1.07
18	17.56	19.45	59.68	2.26	1.05
24	17.52	19.02	59.88	2.34	1.25
Variance Decomposition of Call money rate (r)					
Period	Output	Core	NEER	Call rate	Money supply
1	0.73	0.37	1.54	97.36	0.00
3	2.22	1.44	6.02	89.63	0.69
6	3.15	6.78	6.37	82.85	0.85
12	5.15	6.96	10.59	76.18	1.12
15	6.57	7.4	10.85	73.83	1.35
18	7.19	7.94	10.68	72.69	1.5
24	7.25	8.18	11.21	71.81	1.54
Variance Decomposition of Money supply (M)					
Period	Output	Core	NEER	Call rate	Money supply
1	0.17	0.01	1.68	1.31	96.83
3	0.57	0.11	3.41	1.24	94.67
6	7.44	0.79	4.44	0.86	86.47
12	22.66	3.02	2.67	0.71	70.94
15	28.34	3.71	2.6	1.1	64.24
18	31.8	4.13	3.33	1.64	59.1
24	33.09	3.93	7.03	2.57	53.38

Table 5.5: Variance Decomposition for WPI Ex-Food and Fuel (Core prices) Targeting Case

Variance Decomposition of Output (y)					
Period	Output	Core	NEER	Call rate	Money supply
1	100	0.00	0.00	0.00	0.00
3	92.55	0.31	4.5	2.57	0.07
6	85.22	2.74	6.38	5.35	0.31
12	64.83	2.52	22.17	8.71	1.77
15	56.84	2.57	29.09	8.27	3.23
18	51.68	3.48	32.43	7.59	4.82
24	46.9	5.84	32.86	6.86	7.55
Variance Decomposition of Core prices					
Period	Output	Core	NEER	Call rate	Money supply
1	0.23	99.77	0.00	0.00	0.00
3	1.09	97.42	1.06	0.37	0.07
6	6.06	89.64	1.58	2.39	0.34
12	21.67	66.86	5.6	5.64	0.24
15	23.02	59.06	10.6	7.1	0.22
18	21.56	53.43	16.87	7.81	0.32
24	18.66	47.22	25.66	7.37	1.09
Variance Decomposition of NEER (e)					
Period	Output	Core	NEER	Call rate	Money supply
1	0.65	8.89	90.47	0.00	0.00
3	3.31	10.15	84.42	1.53	0.59
6	6.35	10.3	81.3	1.42	0.63
12	16.39	15.77	65.34	1.46	1.04
15	17.72	18.22	61.07	1.92	1.06
18	17.6	19.17	59.92	2.28	1.03
24	17.52	18.74	60.16	2.35	1.23
Variance Decomposition of Call money rate (r)					
Period	Output	Core	NEER	Call rate	Money supply
1	0.00	0.42	0.00	99.58	0.00
3	2.72	1.52	2.89	92.17	0.7
6	3.87	6.89	3.41	84.99	0.85
12	5.8	7.06	7.94	78.08	1.12
15	7.27	7.5	8.22	75.65	1.36
18	7.94	8.04	8.09	74.43	1.5
24	8.00	8.27	8.75	73.44	1.54
Variance Decomposition of Money supply (M)					
Period	Output	Core	NEER	Call rate	Money supply
1	0.1	0.02	1.33	1.34	97.21
3	0.56	0.11	3.5	1.27	94.57
6	7.35	0.79	4.41	0.88	86.57
12	22.8	3.02	2.7	0.72	70.76
15	28.68	3.69	2.75	1.12	63.76
18	32.25	4.09	3.67	1.66	58.33
24	33.59	3.86	7.79	2.57	52.18

Figure 5.1: Call Money Rate and Federal Funds Rate

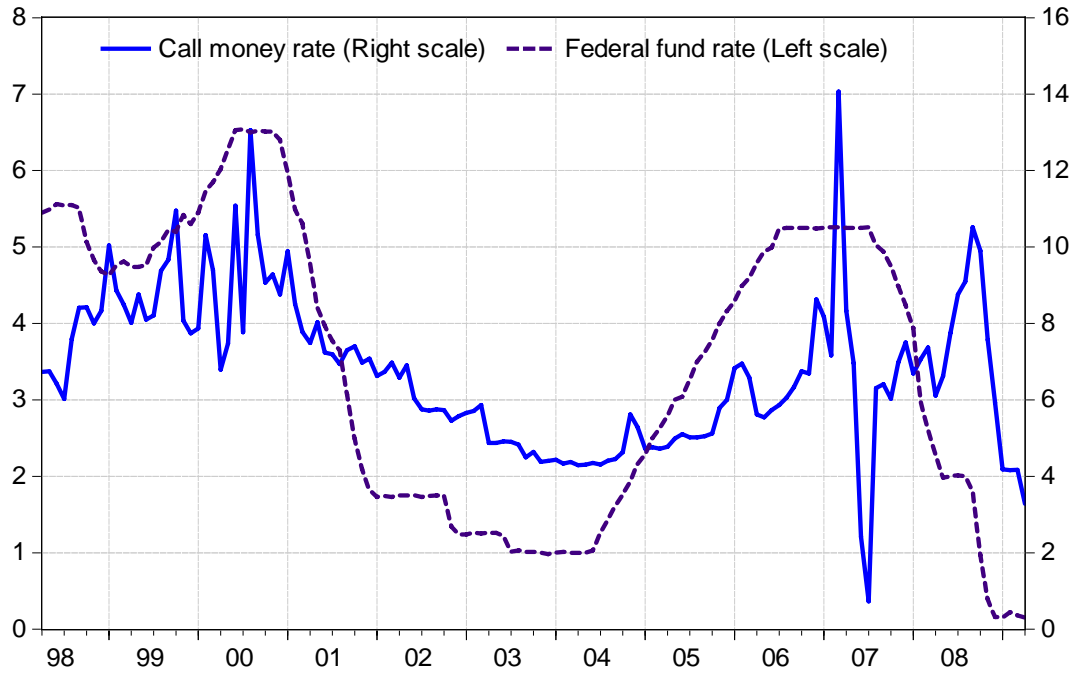
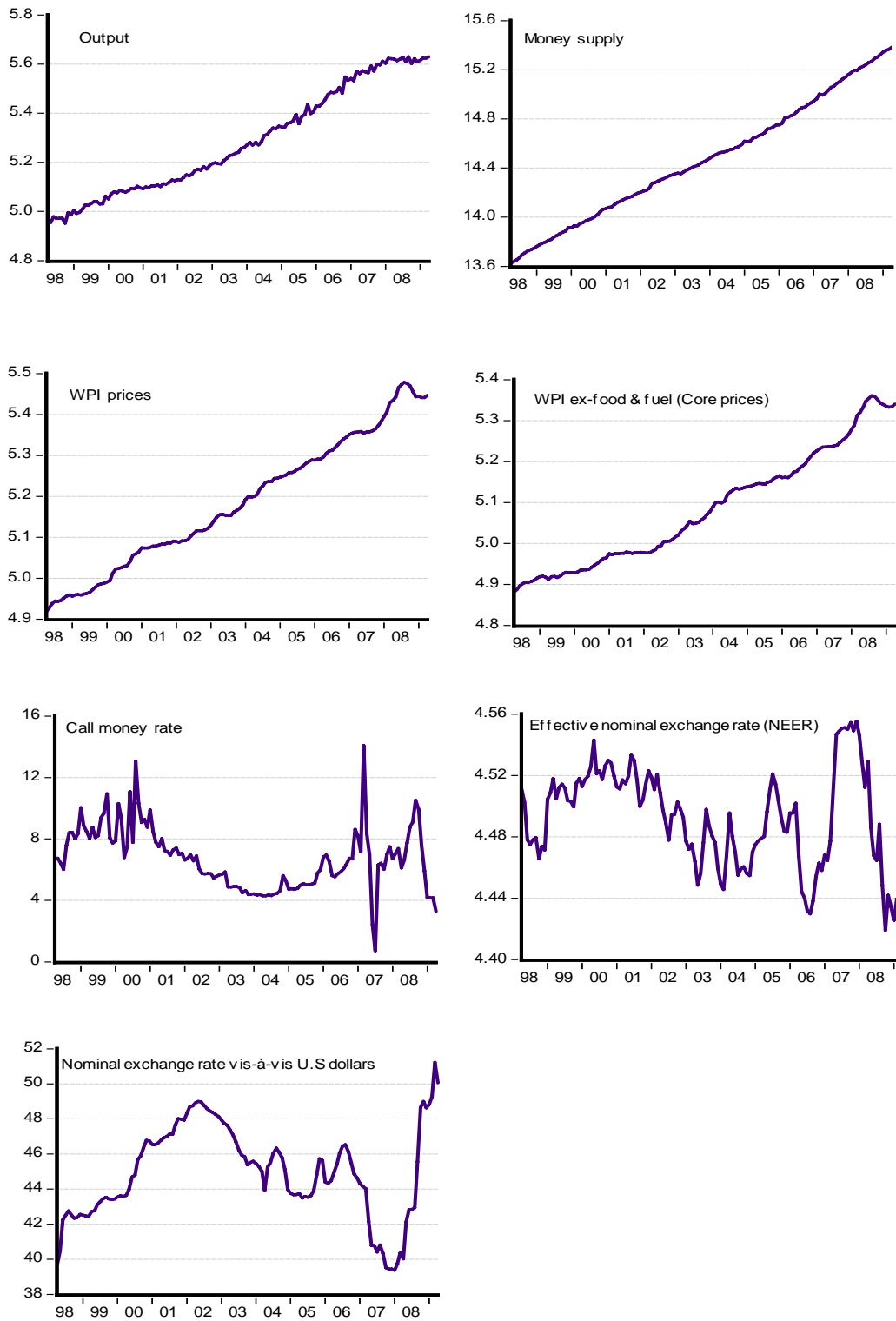


Figure 5.2: Data Used for the Estimation of the VAR, April-1998-April- 2009



**Figure 5.3: Impulse Responses to Call Money Interest Rate Shock:
Benchmark Model (WPI)**

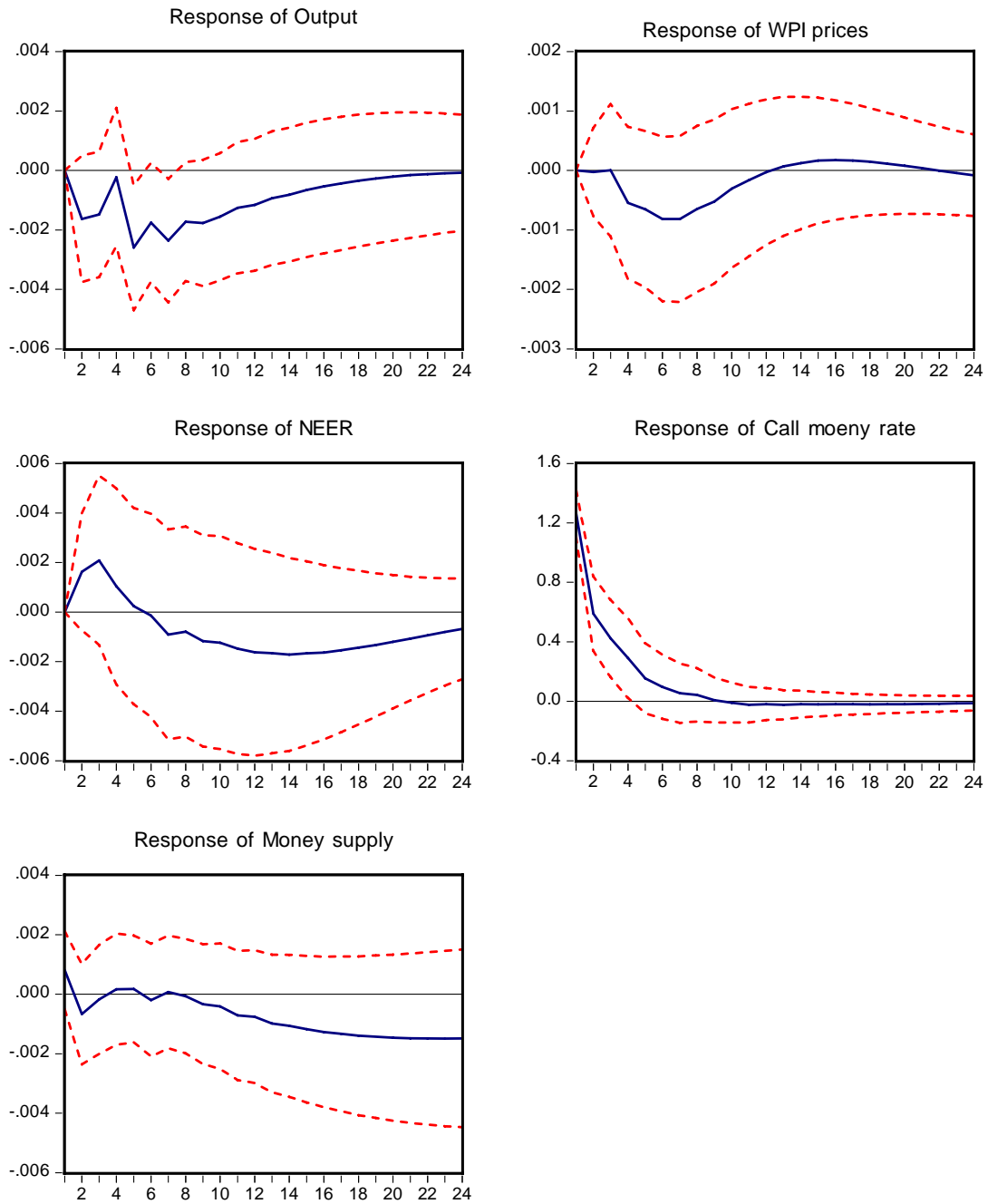


Figure 5.4: Impulse Responses to Call Money Interest Rate Shock: Price Puzzle

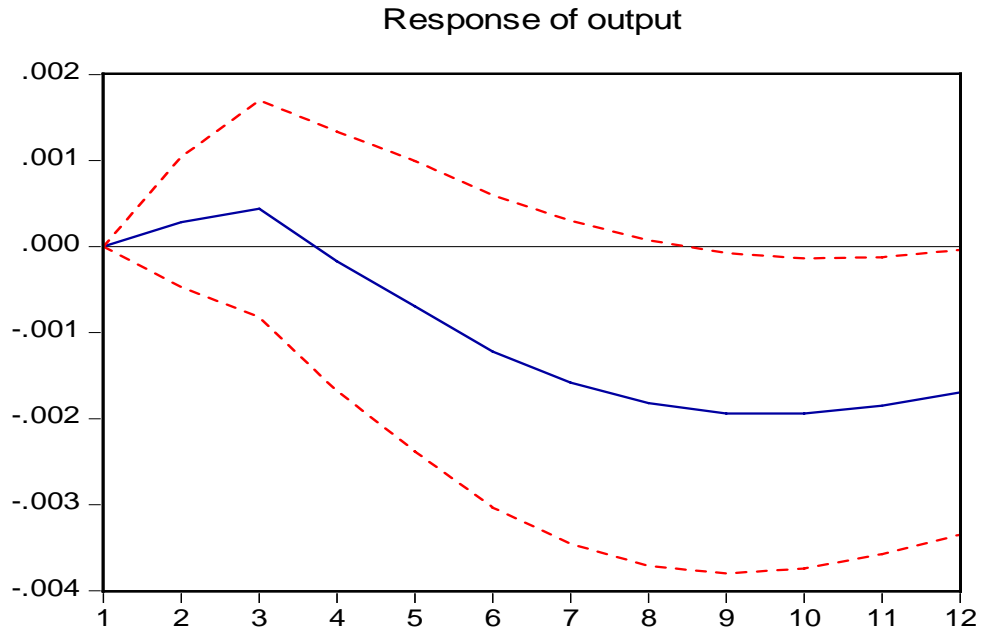
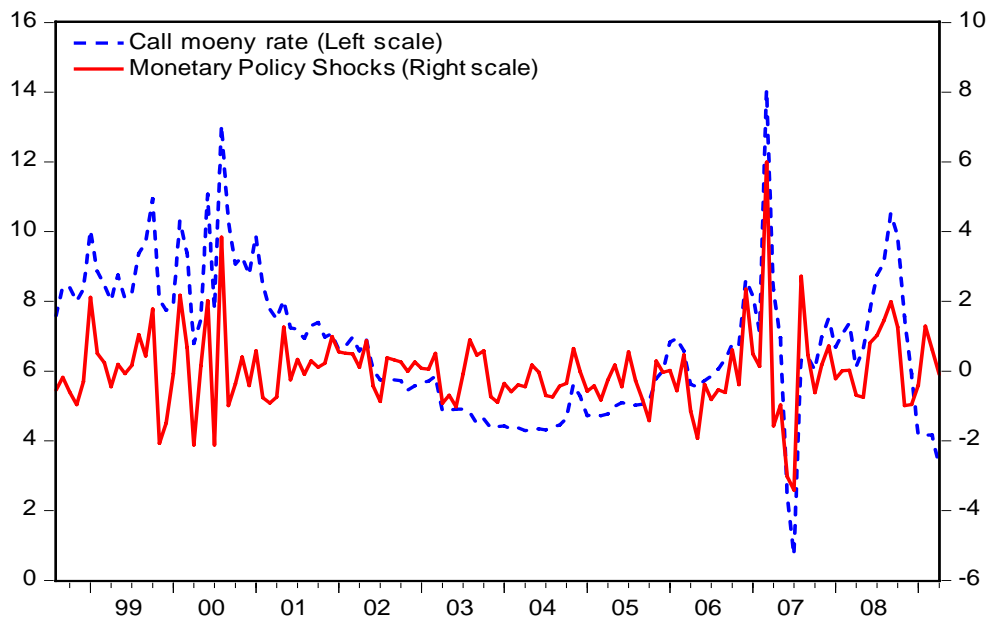
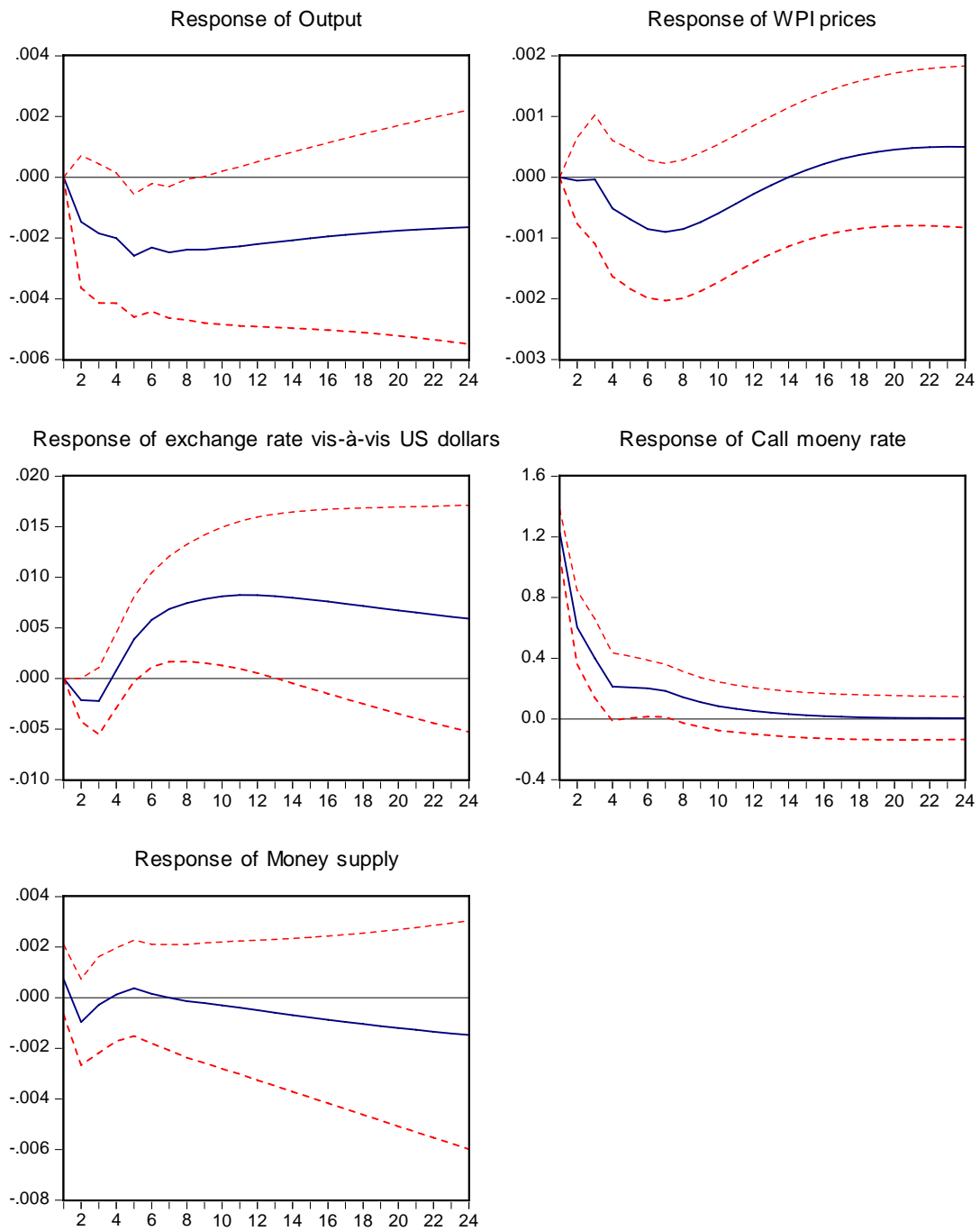


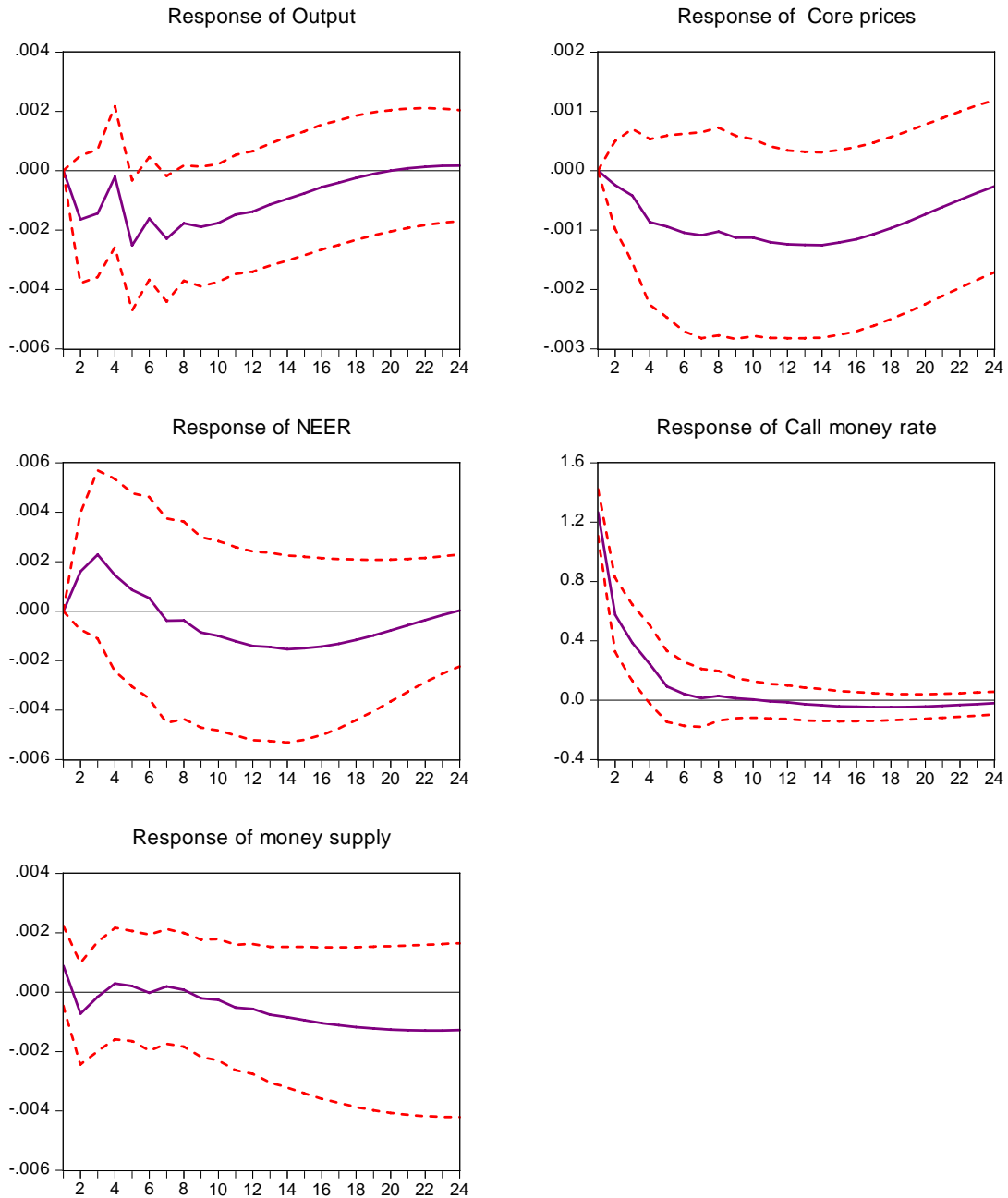
Figure 5.5: Monetary Policy Shocks (call money rate shocks) in a Benchmark Model (WPI) versus Growth in Actual Call Money Rate



**Figure 5.6: Impulse Responses to Call Money Interest Rate Shock:
Benchmark Model Using Nominal Exchange Rate vis-à-vis the US dollars (₹/\$)**

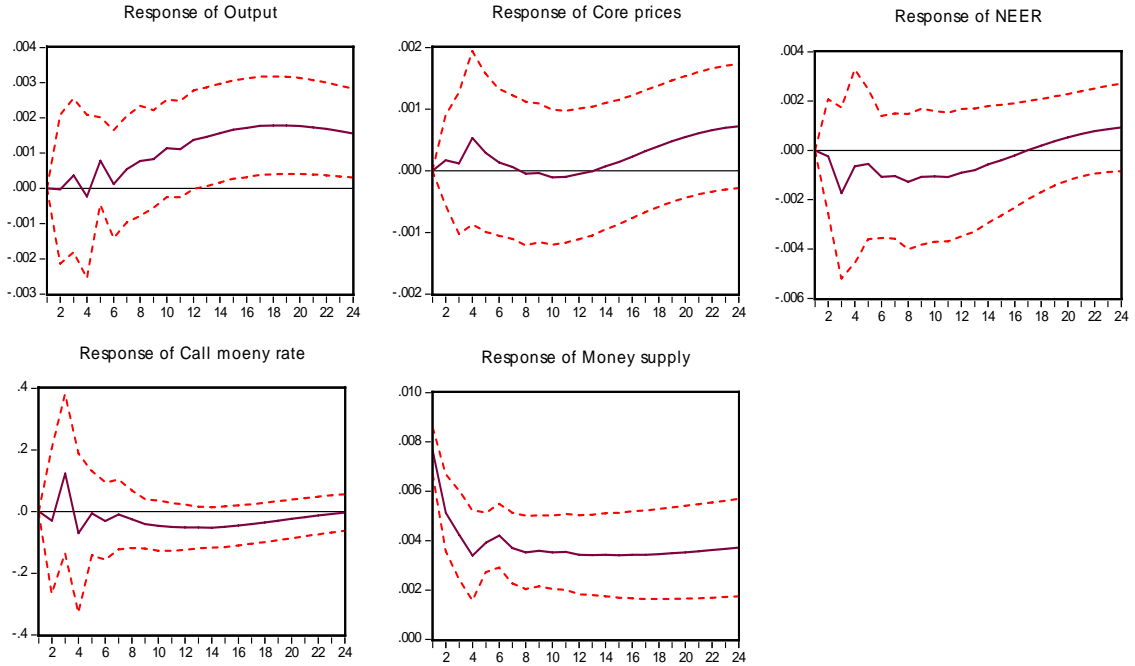


**Figure 5.7: Impulse Responses to Call Money Interest Rate Shock:
Benchmark Model core prices (WPI ex-food and fuel)**



**Figure 5.8: Impulse Responses to Positive Money Supply Shock:
Benchmark Model with Core Prices and WPI Prices**

Impulse Responses to Positive Money Supply Shock: Benchmark Model with Core Prices



Impulse Responses to Positive Money Supply Shock: Benchmark Model with WPI Prices

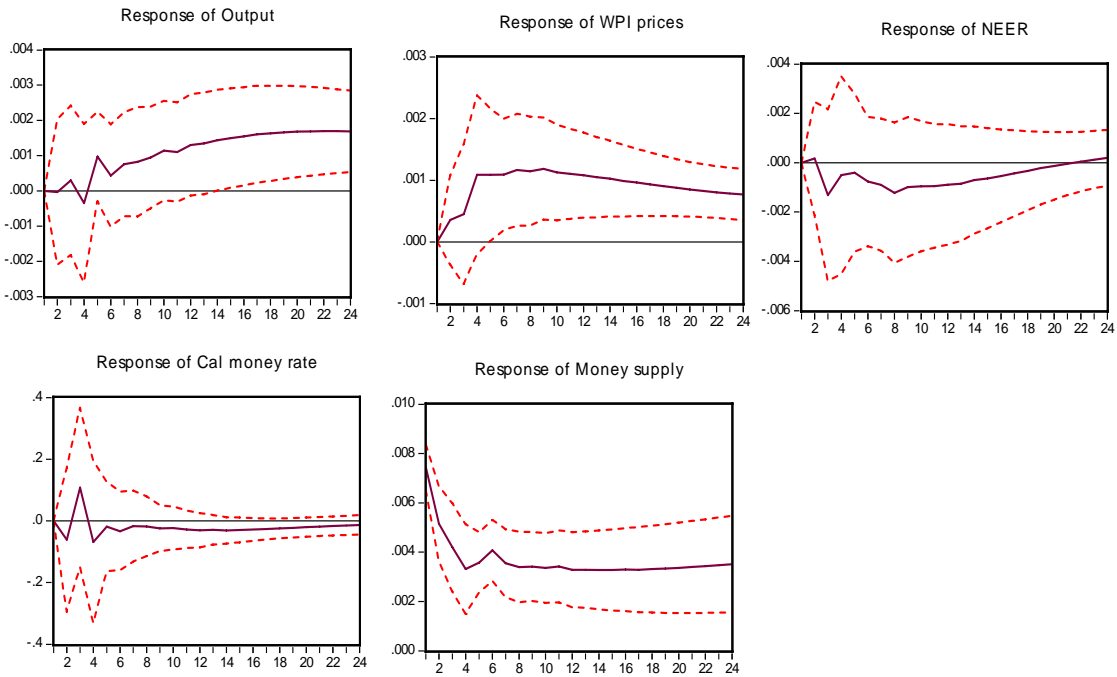
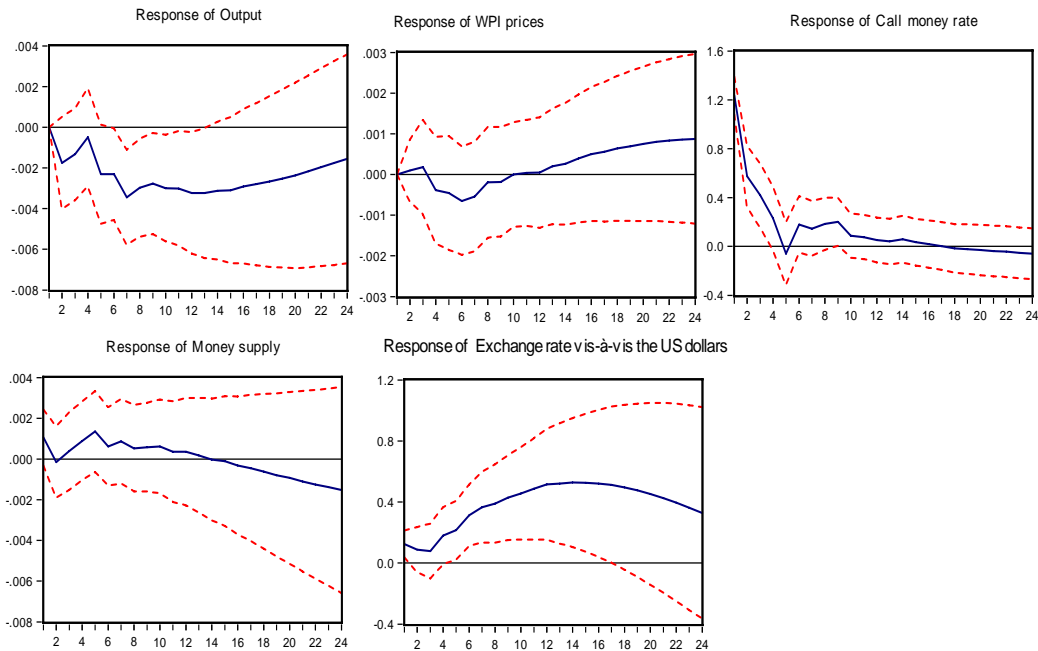
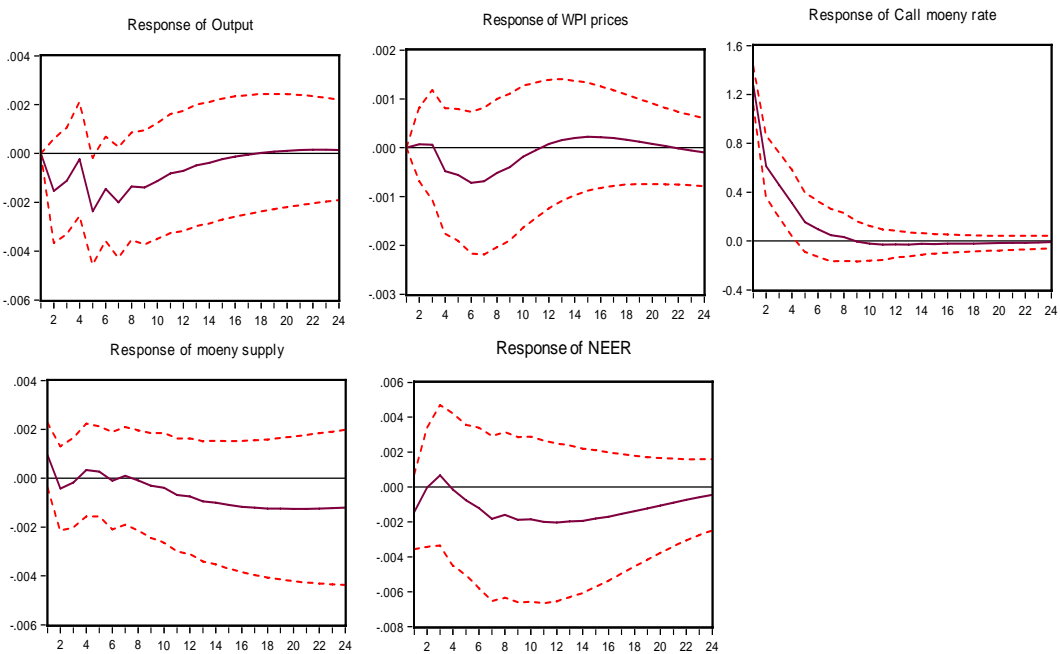


Figure 5.9: Impulse Responses to Call Money Interest Rate Shock in Alternative Recursive Ordering Case (Using Nominal Exchange Rate vis-à-vis the US dollars and NEER): Robustness Analysis

Impulse Responses to Call Money Interest Rate Shock: Using Nominal Exchange Rate vis-à-vis the US dollars



Impulse Responses to Call Money Interest Rate Shock: Using NEER



**Figure 5.10: Impulse Responses to Call Money Interest Rate Shock
Non-recursive VAR Model: A Robustness Analysis**

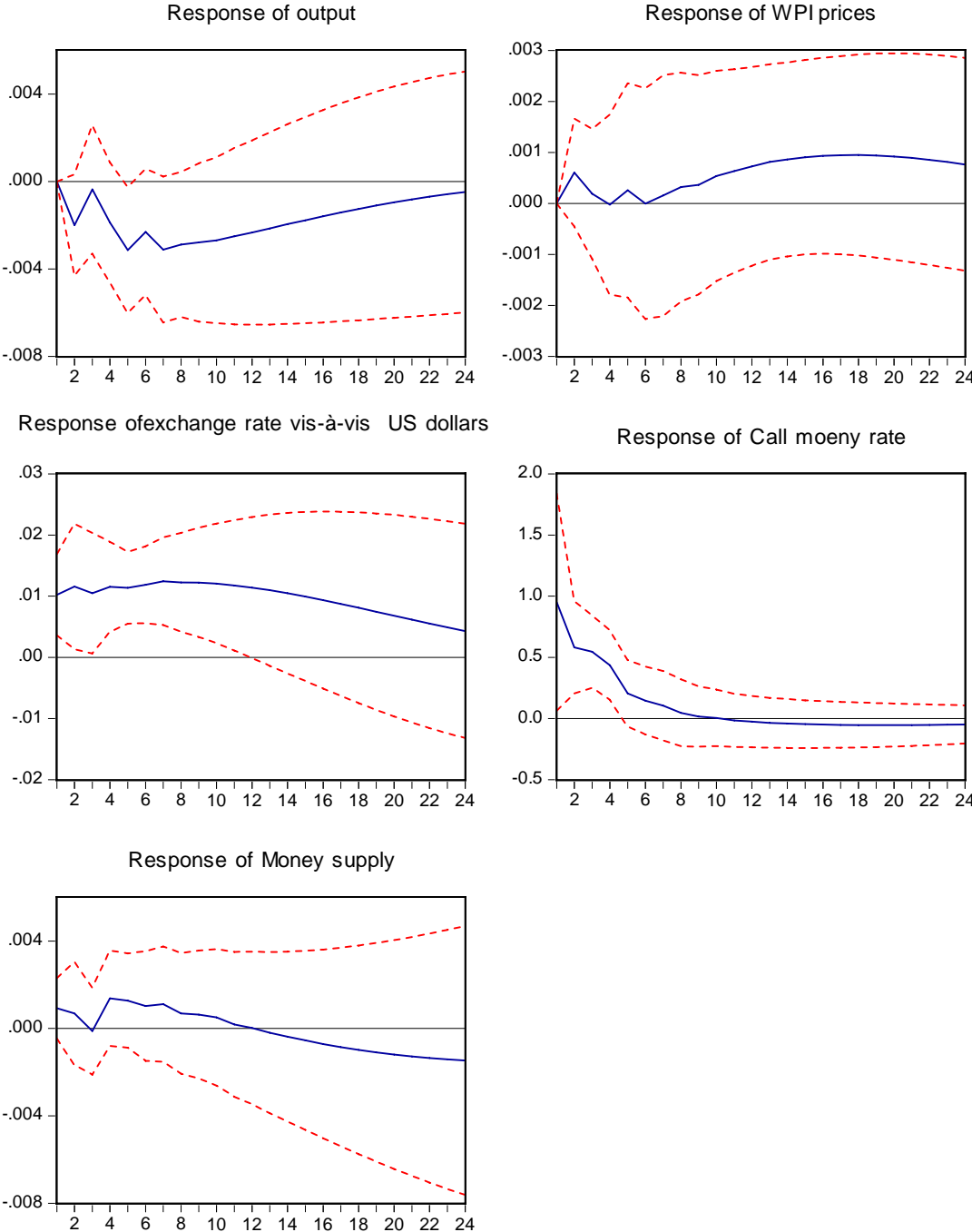
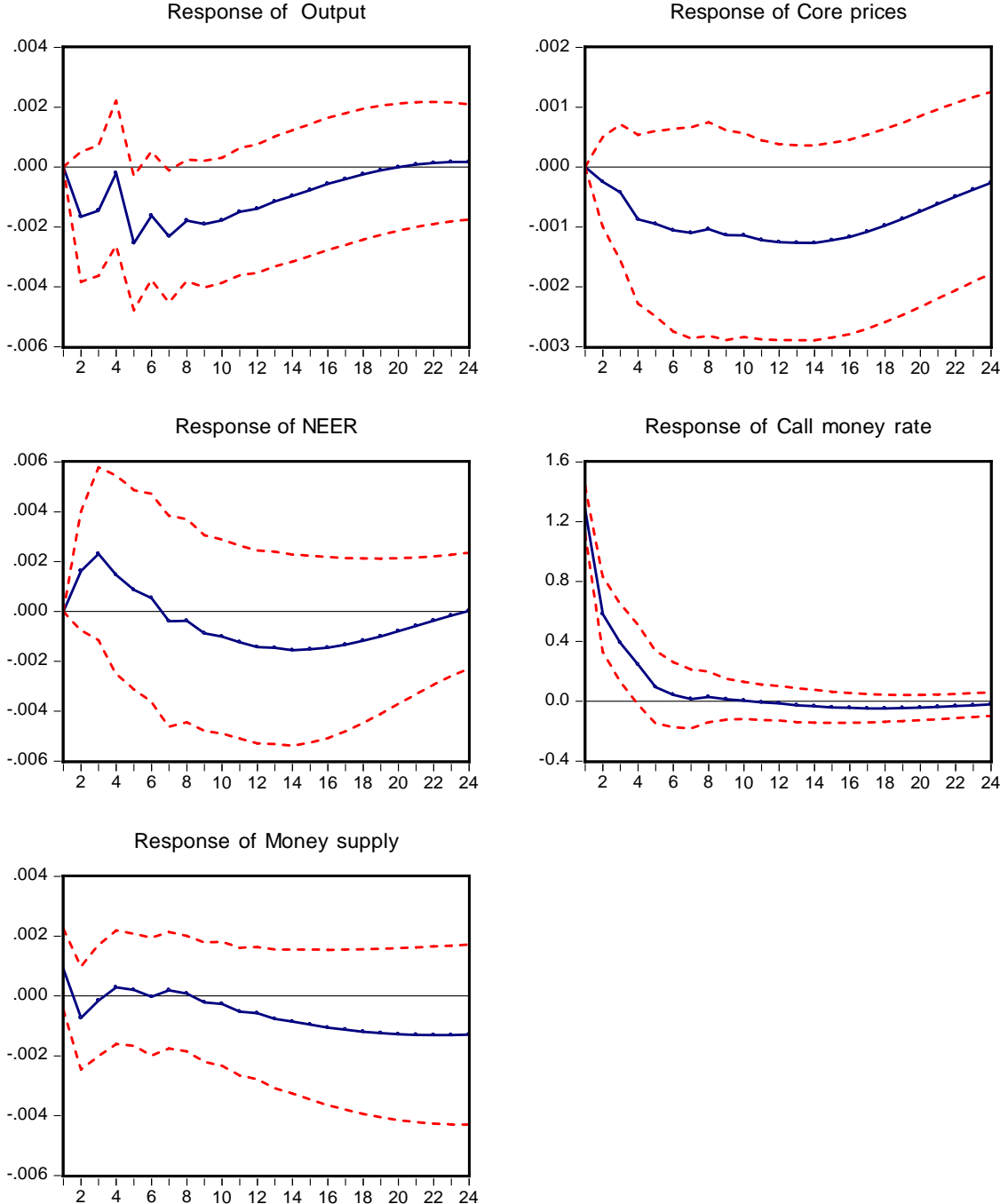


Figure 5.11: Impulse Responses to Call Money Interest Rate Shock in WPI Ex-Food and Fuel Targeting Case (Alternative Non-recursive VAR Model)



CHAPTER 6

SUMMARY AND CONCLUSION

Summary of the Study

An attempt has been made in this thesis to study two issues relating to core inflation. The first task is to construct useful core inflation measures and their evaluation for India and the second is its operational use and role in monetary policy framework. Towards these tasks, the study outlined five objectives which constituted three empirical chapters of the thesis. We briefly summaries each chapter of the thesis below.

Before proceeding to fulfill those objectives of the study, we first studied various aspects of core inflation, its measurement and empirical criteria issues in some detail. Since, there is no agreed definition and method of core inflation in the literature, a wide variety of alternative approaches have been proposed for measurement of core inflation. Chapter 2 reviews various definitions of core inflation and various existing alternative theoretical approaches to measuring core inflation, evaluating their potential advantages and disadvantages and discussing the theoretical and empirical issues arising in measurement of core inflation.

Given lack of an agreed single core inflation measure, different statistical criteria have been proposed and applied in order to judge the best measure among alternatives. Indeed, the various empirical criteria by which measures of core inflation are evaluated are implicitly linked to uses of core inflation in monetary policy. Hence, reviews of various empirical criteria of core inflation were carried out by linking these criteria in a common conceptual framework in this chapter. Thus, chapter 2 provides a blue print for subsequent empirical tasks of this thesis. It draws some important observation and conceptual framework of statistical core measures which guide for computation and evaluation of core measures in subsequent chapters.

Having gained knowledge about various aspects of measuring core inflation and its

potential use and role in monetary policy in Chapter 2, this knowledge is applied in subsequent chapters to fulfill the objectives of the study. Towards these objectives, Chapter 3 applied the asymmetric trimmed mean approach to measuring core inflation in India. This chapter computed 168 trimmed mean measures and subsequently evaluated them according to pre-specified empirical criteria, in order to find the best measure in a class of the trimmed means measures. For this purpose, the chapter 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. Among the five asymmetric trimmed mean, asymmetric trimmed mean: TM (55.4, 25) was found to have the smallest relative variance. TM (55.4, 25) corresponds 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. This chapter 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.

In chapter 4, an attempt was made to construct other alternative statistical based core measures, and providing their methodology on the construction of core measures for India. Before getting on with computations, this chapter presented the existing research on core inflation in India, which clearly indicated that the research on core inflation in India has remained rather neglected so far. There is no serious attempt to develop core inflation measures for India. With that in mind, this chapter constructed a total of 28 core inflation measures based on different statistical methods. Some of these were computed for first time in Indian case such as persistence weighted, standard deviation double weighted, month by month exclusion (dynamic trimmed mean) and asymmetric trimmed mean core measures. Subsequently, an empirical evaluation and comparison of those estimated core measures was conducted in a systematic testing framework in order to suggest useful core measures for India.

As a first step, this chapter applied Marques *et al* (2000) 'UAE' tests. The results of UAE

test suggested that most of the core measures satisfy attractor property of core inflation hence they can be leading indicator of headline inflation. Among alternative core measures only trimmed mean and HP trend measure passed all the three tests.

To evaluate further the relevance of core measures from a monetary policy point of view, the study then applied two standard test of core inflation viz., tracking trend inflation and forecasting future transient movement in inflation. These two criteria are used to evaluate to what extent different core inflation indicators are useful in providing information about current underlying trend inflation and future movement in headline inflation. Before applying trend inflation criterion, the study selected reference trend inflation measures according to the UAE tests results. The selected trend measures in the RMSE trend evaluation process therefore, guaranteed that they possess necessary properties of underlying trend inflation.

The results suggested that the trend based exponential based core measures, and asymmetric trimmed mean and standard deviation double weighted core measures did the best job in tracking trend inflation of WPI. The results were robust with respect to two selected reference trend inflation viz., CMA-37 and HP trend inflation. Taken together the evidence from within sample analysis and out of sample forecasting evaluation of 'gap' test model, the study found that the results varied across the forecasting horizons. In sample analysis, except conventional ex-food and fuel measures and persistence weighted core measure (WPIPW), most of the core measures performed well. Particularly, the estimated individual coefficient value for asymmetric trimmed means, neo-Edgeworthian based core measures (WPISDS WPISDRPDW, WPISDSDW, dynamic trimmed mean (WPIMBM20), and exponential based core measures were found very close to 1, suggesting that the deviation between these core measures and WPI inflation are not persistent. Indeed are temporary at forecasting horizon of 18 and 24 months. This further implies that after shock to WPI inflation, WPI inflation return to these core inflation rates over 18 to 24 months horizon.

Among the unbiased core measures that satisfied the null of unbiased predictor in the 'gap' test model, the value of adjusted R-square was highest for trend based core measures at all the three horizons. While, evidence from DM test and rank of average RMSEs of out

of sample forecast suggested that the HP trend measure, asymmetric trimmed mean, median, and double-weighted persistence core measure (WPIPDW) forecast actual headline deviation well. It should also be noted that the conventional ex-food and fuel core measures did not satisfy any of the basic properties of core inflation. The particular attention has been focused on systematic bias in the core measures towards the end of analysis.

Towards fourth and fifth objectives, Chapter 5 analyzed core inflation and monetary policy in India in VAR framework over a period that covers the term after the RBI adopted a multiple indicator approach. The study first identified monetary policy shocks in a recursive structure of VARs by modelling current policy reaction function of the RBI and structure of economy. In this recursive-VAR approach, we assumed that RBI modulates the call money rate after observing the current values of prices, output and nominal exchange rate. This assumption is consistent with the multiple indicator approach currently followed by the RBI. Considering that the proper identification of monetary policy shock in emerging economies like India is needed to include the world constraint in model, we included exogenous variables namely, federal fund rate and world commodity prices in the model.

The study then examined the dynamic responses of the macroeconomic variables to a call money rate shocks with WPI and WPI core measures in separate benchmark VAR model estimation. Overall, the results for WPI and WPI ex-food and fuel core measure model suggested that the responses of macro variables to call money rate shock were qualitatively consistent with the predictions of theories. Thus, the results can be considered as a good approximation of the monetary policy dynamics in a new policy framework of RBI.

It should be noted that the price puzzle, which emerged when the benchmark model estimated without exogenous variables, disappeared when the exogenous variables were included in the benchmark model. However, the study found one major difference that unlike in the case of WPI model, the response of core prices declined swiftly and immediately following a positive call money interest rate shock. Further, the decline in the price level was persistent over the 24 months horizon. This gives some evidence that

monetary policy would work more effectively on core prices, which by definition represent trend prices, reflecting aggregate demand side pressure in the economy.

The study further examined results of impulse responses to a positive shock to money supply. The results suggested that the transmission of money supply shock were stronger for WPI prices compared to the case of core prices, while interest rate channel was stronger for core prices. Subsequently, the study examined robustness of the benchmark VAR results with alternative ordering and non-recursive identification schemes, which were in the spirit of Kim and Roubini (2000), and Bredin and Reilly (2004). The results indicated that the impulse responses were not sensible as there was price puzzle and exchange rate puzzle.

The study then generated a scenario in the benchmark recursive VAR model, where it assumed that RBI sets its policy instrument only after looking at the WPI ex-food and fuel core prices. The results indicated that the responses of macro variables to a positive one standard deviation shock to call money rate was not very different from the results of impulse responses from the benchmark recursive core price model. It is important to note that this chapter also used other types of core measures in place of WPI ex-food and fuel core measure in the benchmark VAR model. The results however, show 'price puzzle'. This is because the relationship between monetary policy and inflation measures in the sample data is sensitive to type of inflation measures used in the monetary policy decisions.

Policy Implications

The findings of the study have some important policy implications which are as follows:

Given the skewness in the distribution of price changes in Indian data, the symmetric trimmed mean estimator produces a core inflation rate that systematically underestimates the WPI inflation rate. Therefore, the symmetric trimmed mean is not a useful trend inflation indicator of WPI inflation in India.

Considering that "each measure of core inflation can provide some particular insight into how inflation is evolving", we suggest that the asymmetric trimmed mean (TM 54.5, 25), WPIEX25%, dynamic trimmed means, double weighted standard deviation based core

measures (WPISDSDWM, WPISDRPDW) can be used in analyzing and tracking underlying trend inflation development while trend based core measures can be useful indicators of future trend inflation for the conduct of monetary policy in India. It is here worth a mention that recent demand shock to oil prices and persistency in commodity prices particularly in an emerging economy like India suggest that monetary authority should consider different useful core inflation indicators in analyzing the underlying inflation development and assessing outlook for inflation in the conduct of monetary policy.

Based on VAR analysis, the results suggested that the interest rate channel was stronger for core prices, while transmission of money supply shock was stronger for WPI prices compared to the case of core prices. Given that RBI generally operates its monetary management through interest rate channel under current policy framework, core inflation measures are thus seen to be more appropriate measures. Further, it appears that although RBI may not have explicitly stated about the inflation targeting but it has been implicitly targeting WPI ex-food and fuel type core measures and considering information on these core measures when it comes to adjust policy instruments from time to time.

The implicit use of such WPI ex-food and fuel type core measures in RBI's policy decision has been documented and analyzed in the various RBI policy reports, for instance Y.V. Reddy (1999) noted that ".....dilemma arises when inflation rate accelerates because of supply shocks, which are expected to be temporary. This, for example, was the situation last year when, until October, inflation was accelerating due to lower availability of a few primary commodities. The Reserve Bank at that time chose not to tighten monetary policy in the expectation that the price rise would reverse itself later in the year when agricultural supplies improve. In retrospect, this judgement turned out to be correct" (p. 7). Notwithstanding this, given empirical disadvantages associated with conventional WPI ex-food and fuel type core measures, we suggest that the RBI should consider other useful core measures to generate overall outlook on dynamics of inflation development which can be then fed into the forward looking monetary policy formation.

Appendices:

Appendix I: Data sources

Data on disaggregated component indices of WPI were collected from Database on Indian Economy: RBI's Data Warehouse website through hyperlink:

<http://dbie.rbi.org.in/InfoViewApp/listing/main.do?appKind=InfoView&service=%2FInfoViewApp%2Fcommon%2FappService.do>

Data for domestic variables: nominal effective exchange rate (NEER), nominal exchange rate vis-à-vis the US dollars, call money rate, IIP, money supply (M3), were collected from the, 'Handbook of Statistics on the Indian economy, 2005 and 2009'.

For world commodity prices data has been sourced from the IMF <http://www.imf.org/external/np/res/commod/index.asp> while federal funds rate data sourced from the Federal Reserve Bank of Set. Louis <http://research.stlouisfed.org/fred2/categories/118>

Appendix II: The New Weighting System of Reweighted Based Core Inflation Measures

Code and Name of 69 Component indexes of WPI	WPI	WPI SDSM	WPI SDSDWM	WPI SDRPM	WPI SDRPDWM
a1. Cereals	4.41	2.18	5.78	2.12	5.70
a2. Pulses	0.60	0.90	0.33	1.02	0.37
b1. Vegetables	1.46	0.26	0.23	0.29	0.26
b2. Fruits	1.46	0.46	0.41	0.52	0.47
c. Milk	4.37	1.86	4.89	1.98	5.28
d. Eggs,Meat & Fish	2.21	1.06	1.41	1.18	1.58
e. Condiments & Spices	0.66	0.92	0.37	1.02	0.41
f. Other Food Articles	0.24	0.50	0.07	0.56	0.08
a. Fibres	1.52	0.81	0.74	0.93	0.87
b. Oil Seeds	2.67	1.01	1.61	1.17	1.90
c. Other Non-Food Articles	1.95	1.85	2.17	2.01	2.39
a. Metallic Minerals	0.30	0.27	0.05	0.30	0.06
b. Other Minerals	0.19	1.09	0.12	1.24	0.14
A. Coal Mining	1.75	1.10	1.16	1.19	1.28
B. Minerals Oils (Petrol and Gas)	6.99	0.78	3.28	0.96	4.08
C. Electricity	5.48	1.34	4.40	1.53	5.12
a. Dairy Products	0.69	2.00	0.83	1.98	0.83
b. Canning, Preserving & Processing of fish	0.05	0.49	0.01	0.53	0.01
c. Grain Mill Products	1.03	1.10	0.69	1.21	0.76
d. Bakery Products	0.44	1.67	0.44	1.66	0.45
e. Sugar,Khandsari & Gur	3.93	1.18	2.79	1.26	3.01
f. Manufacture of Common Salts	0.02	0.46	0.01	0.50	0.01
g. Cocoa, Chocolate Sugar & Confectionery	0.09	2.04	0.11	1.96	0.10
h. Edible Oils	2.76	1.19	1.96	1.37	2.29
i. Oil Cakes	1.42	0.67	0.57	0.77	0.66
j. Tea & Coffee Processing	0.97	0.56	0.32	0.62	0.36
k. Other Food Products n.e.c	0.15	2.43	0.23	2.24	0.21
a. Wine Industries	0.27	0.80	0.13	0.89	0.15
b. Malt liquor	0.04	1.08	0.03	1.09	0.03
c. Soft Drinks & Carbonated Water	0.05	1.01	0.03	1.07	0.03
d. Manufacture of Bidi, Cigarettes,Tobacco & Zarda	0.97	2.41	1.41	2.23	1.32
a1. Cotton Yarn	3.31	1.07	2.14	1.20	2.42
a2. Cotton Cloth (Mills)	0.90	2.87	1.56	2.57	1.42
b1. Man Made Fibre	4.41	1.42	3.77	1.54	4.15
b2. Man Made Cloth	0.31	2.81	0.53	2.41	0.46
c. Woolen Textiles	0.19	1.13	0.13	1.25	0.14
d. Jute Hemp & Mesta Textiles	0.68	0.80	0.32	0.87	0.36
(D) Wood & Wood Products	0.17	0.79	0.08	0.86	0.09
a. Paper & Pulp	1.23	1.74	1.29	1.76	1.32
b. Manufacture of Board	0.24	1.06	0.15	1.13	0.16
c. Printing & Publishing of Newspapers, Periodicals	0.58	0.80	0.28	0.84	0.30
(F) Leather & Leather Products	1.02	1.16	0.71	1.25	0.78
a. Tyres & Tubes	1.29	1.62	1.25	1.72	1.35
b. Plastic Products	0.94	2.22	1.25	2.22	1.27
c. Other Rubber & Plastic Products	0.17	0.80	0.08	0.87	0.09
a. Basic Heavy Inorganic Chemical	1.45	1.10	0.96	1.25	1.11
b. Basic Heavy Organic Chemical	0.45	0.53	0.14	0.60	0.17
c1. Fertilisers	3.69	1.71	3.78	1.90	4.28
c2. Pesticides	0.47	1.23	0.35	1.31	0.38

d. Paints, Varnishes & Laquers	0.50	1.89	0.56	1.76	0.53
e. Dyestuffs & Indigo	0.18	2.10	0.22	2.14	0.23
f. Drugs & Medicines	2.53	1.40	2.13	1.48	2.28
g. Perfumes, Cosmetics, Toiletries etc	0.98	1.85	1.09	1.76	1.05
h. Turpentine, Synthetic Resins and Plastic materials	0.75	0.54	0.24	0.60	0.27
i. Matches, Explosives and Other Chemicals n.e.c	0.94	2.42	1.37	2.22	1.27
a. Structural Clay Products	0.23	1.58	0.22	1.63	0.23
b. Glass Earthenware Chinaware & their products	0.24	1.28	0.18	1.36	0.20
c. Cement	1.73	1.23	1.28	1.32	1.40
d. Cement Slate & Graphite Products	0.32	1.44	0.28	1.54	0.30
a1. Iron & Steel	3.64	0.93	2.04	1.10	2.43
a2. Foundries for Casting Forging & Structural	0.90	1.23	0.66	1.41	0.77
a3. Pipes Wires Drawing & Others	1.59	1.69	1.61	1.91	1.85
a4. Ferro Alloys	0.09	0.84	0.04	0.93	0.05
b. Non-Ferrous Metals	1.47	1.48	1.31	1.58	1.42
c. Metal Products	0.67	2.96	1.19	2.53	1.03
a. Non-Electrical Machinery & Parts	3.38	4.44	9.03	3.24	6.67
b. Electrical Machinery	4.98	3.15	9.44	2.94	8.94
a. Locomotives Railway Wagon & Parts	0.32	2.50	0.48	2.17	0.42
b. Motor Vehicles, Motorcycles, Scooters, bicycles	3.98	4.72		3.39	8.22
& parts			11.28		
Sum of weight	100.00	100.00	100.00	100.00	100.00

Cont...

Appendix II: The New Weighting System of Reweighted Based Core Inflation Measures

Code and Name of 69 Component indexes of WPI	WPI SDRP	WPI SDRPDW	WPISDS	WPI SDSDW	WPIPW	WPIPDW
a1. Cereals	1.49	4.10	1.51	4.15	2.74	7.66
a2. Pulses	0.94	0.35	0.93	0.35	2.34	0.90
b1. Vegetables	0.44	0.40	0.43	0.39	0.00	0.00
b2. Fruits	0.94	0.86	0.92	0.83	0.00	0.00
c. Milk	2.66	7.24	2.86	7.76	0.35	0.97
d. Eggs,Meat & Fish	1.56	2.15	1.52	2.09	0.00	0.00
e. Condiments & Spices	0.77	0.32	0.75	0.31	1.47	0.62
f. Other Food Articles	0.54	0.08	0.53	0.08	1.25	0.19
a. Fibres	0.74	0.71	0.72	0.69	2.21	2.14
b. Oil Seeds	0.90	1.50	0.87	1.45	2.08	3.52
c. Other Non-Food Articles	2.57	3.13	2.43	2.95	0.00	0.00
a. Metallic Minerals	0.21	0.04	0.20	0.04	1.08	0.20
b. Other Minerals	1.56	0.18	1.49	0.17	0.27	0.03
A. Coal Mining	1.44	1.57	1.38	1.50	0.18	0.20
B. Minerals Oils Petrol and Gas	0.90	3.92	0.85	3.68	0.76	3.37
C. Electricity	1.89	6.45	1.77	6.04	0.00	0.00
a. Dairy Products	1.73	0.74	1.70	0.73	1.89	0.83
b. Canning, Preserving & Processing of fish	0.70	0.02	0.69	0.02	0.00	0.00
c. Grain Mill Products	1.03	0.67	1.00	0.64	1.93	1.27
d. Bakery Products	1.85	0.51	1.78	0.49	0.25	0.07
e. Sugar,Khandsari & Gur	1.00	2.45	1.01	2.46	4.31	10.75
f. Manufacture of Common Salts	0.29	0.00	0.28	0.00	1.20	0.02
g. Cocoa, Chocolate Sugar & Confectionery	2.82	0.15	2.74	0.15	1.59	0.09
h. Edible Oils	0.85	1.47	0.82	1.40	2.77	4.85

i. Oil Cakes	0.66	0.59	0.65	0.57	1.35	1.22
j. Tea & Coffee Processing	0.69	0.41	0.67	0.40	0.33	0.20
k. Other Food Products n.e.c	1.85	0.18	1.86	0.18	1.51	0.15
a. Wine Industries	1.07	0.18	1.02	0.17	1.46	0.25
b. Malt liquor	1.12	0.03	1.19	0.03	1.36	0.04
c. Soft Drinks & Carbonated Water	1.09	0.04	1.06	0.03	0.76	0.03
d. Manufacture of Bidi, Cigarettes, Tobacco & Zarda	2.31	1.40	2.44	1.48	0.17	0.10
a1. Cotton Yarn	1.15	2.38	1.17	2.41	2.12	4.45
a2. Cotton Cloth (Mills)	2.13	1.20	2.21	1.24	2.29	1.31
b1. Man Made Fibre	1.32	3.63	1.29	3.55	2.28	6.39
b2. Man Made Cloth	2.93	0.57	3.28	0.64	0.00	0.00
c. Woolen Textiles	1.64	0.19	1.62	0.19	0.62	0.08
d. Jute Hemp & Mesta Textiles	0.72	0.30	0.71	0.30	1.55	0.67
(D) Wood & Wood Products	0.66	0.07	0.64	0.07	2.91	0.32
a. Paper & Pulp	1.04	0.80	1.02	0.78	4.30	3.36
b. Manufacture of Board	1.31	0.19	1.27	0.19	0.00	0.00
c. Printing & Publishing of Newspapers, Periodicals	0.81	0.29	0.78	0.28	2.05	0.75
(F) Leather & Leather Products	1.41	0.90	1.37	0.87	0.00	0.00
a. Tyres & Tubes	1.38	1.11	1.37	1.09	0.83	0.68
b. Plastic Products	2.72	1.59	2.65	1.55	1.21	0.72
c. Other Rubber & Plastic Products	1.05	0.11	1.01	0.10	1.02	0.11
a. Basic Heavy Inorganic Chemical	0.94	0.85	0.89	0.80	3.76	3.45
b. Basic Heavy Organic Chemical	0.59	0.17	0.56	0.16	1.49	0.43
c1. Fertilisers	2.27	5.22	2.36	5.43	0.51	1.21
c2. Pesticides	1.26	0.37	1.25	0.37	1.96	0.59
d. Paints, Varnishes & Laquers	1.76	0.54	1.89	0.58	0.92	0.29
e. Dyestuffs & Indigo	2.10	0.23	2.13	0.23	3.32	0.37
f. Drugs & Medicines	1.29	2.04	1.26	1.98	1.66	2.66
g. Perfumes, Cosmetics, Toiletries etc	2.06	1.25	2.06	1.25	0.00	0.00
h. Turpentine, Synthetic Resins and Plastic materials	1.02	0.48	0.98	0.46	0.00	0.00
i. Matches, Explosives and Other Chemicals n.e.c	2.46	1.44	2.63	1.54	1.74	1.04
a. Structural Clay Products	1.74	0.25	1.70	0.24	0.00	0.00
b. Glass Earthenware Chinaware & their products	1.30	0.19	1.26	0.19	1.26	0.19
c. Cement	1.29	1.39	1.25	1.34	2.08	2.28
d. Cement Slate & Graphite Products	1.32	0.26	1.31	0.26	1.79	0.36
a1. Iron & Steel	0.93	2.10	0.88	1.99	1.32	3.04
a2. Foundries for Casting Forging & Structural	1.12	0.63	1.11	0.62	1.07	0.61
a3. Pipes Wires Drawing & Others	1.44	1.42	1.39	1.38	3.76	3.80
a4. Ferro Alloys	0.95	0.05	0.90	0.05	1.20	0.06
b. Non-Ferrous Metals	1.01	0.93	0.95	0.87	4.51	4.21
c. Metal Products	2.80	1.17	2.82	1.17	3.45	1.47
a. Non-Electrical Machinery & Parts	3.61	7.61	3.78	7.94	1.44	3.09
b. Electrical Machinery	2.13	6.63	2.11	6.55	2.76	8.74
a. Locomotives Railway Wagon & Parts	2.04	0.40	2.16	0.43	1.92	0.39
b. Motor Vehicles, Motorcycles, Scooters, bicycles & parts	3.70	9.19	3.91	9.67	1.28	3.24
Sum of weight	100.00	100.00	100.00	100.00	100.00	100.00

**Appendix III: Monthly Estimate of WPI headline Inflation and alternative Core Inflation
Rate: 1995:4 to 2009:4**

	WPI	TM(54.5,2)	TM(55,20)	Median	58th Percentile	WPIEXL	WPI EXFD	WPIEX FD&DFL	WPIEXP
1995M04	11.01	11.38	11.22	9.30	11.66	11.91	10.48	11.45	10.03
1995M05	10.93	11.28	11.36	9.94	11.95	11.80	10.62	11.61	10.35
1995M06	9.74	10.44	10.46	9.12	10.50	10.45	9.83	10.71	9.59
1995M07	9.64	10.16	10.15	8.49	9.75	10.39	9.62	10.53	9.25
1995M08	8.99	9.51	9.42	8.15	9.33	9.63	9.15	9.96	8.97
1995M09	8.97	9.50	9.62	7.84	9.30	9.61	8.79	9.53	8.59
1995M10	8.54	8.96	9.10	8.02	8.66	9.11	8.53	9.22	8.16
1995M11	8.35	8.19	8.20	7.72	8.61	8.88	8.28	8.91	8.14
1995M12	6.70	6.05	6.00	5.02	6.09	6.96	6.69	7.01	6.84
1996M01	5.12	5.16	5.21	3.61	5.70	5.13	5.64	5.76	5.93
1996M02	4.59	4.60	4.55	2.53	6.09	4.50	4.78	4.71	5.62
1996M03	4.64	5.15	5.19	3.93	5.32	4.56	4.31	4.15	5.32
1996M04	3.77	4.76	4.79	3.81	4.46	4.04	2.93	3.09	3.80
1996M05	3.70	4.24	4.30	3.90	4.20	3.95	2.46	2.52	2.92
1996M06	3.65	4.65	4.76	4.00	5.46	3.88	2.23	2.24	2.38
1996M07	4.31	5.11	5.13	4.08	5.22	3.14	3.17	1.53	3.53
1996M08	4.89	5.98	5.97	4.79	5.47	3.68	3.75	2.06	3.92
1996M09	5.05	5.77	5.73	4.21	5.87	3.87	4.07	2.44	4.15
1996M10	4.50	4.96	5.08	2.71	5.36	3.21	3.28	1.48	3.58
1996M11	4.38	5.05	5.22	4.46	5.50	2.98	3.04	1.09	3.37
1996M12	5.19	5.33	5.47	4.46	5.88	3.91	3.23	1.32	3.68
1997M01	5.12	5.16	5.32	4.08	5.88	3.83	2.95	0.98	3.30
1997M02	5.43	5.47	5.59	4.41	5.45	4.21	3.27	1.39	3.43
1997M03	5.41	6.10	6.15	4.83	5.71	4.18	3.96	2.20	3.99
1997M04	5.80	6.65	6.60	4.85	6.67	3.80	4.87	2.24	5.00
1997M05	4.98	5.88	5.68	4.58	4.72	2.87	5.19	2.63	5.39
1997M06	5.00	5.63	5.43	4.45	4.99	2.91	5.60	3.13	6.05
1997M07	3.54	3.55	3.58	3.27	3.63	2.73	3.80	2.85	4.21
1997M08	3.21	3.64	3.45	2.49	3.30	2.47	3.37	2.50	3.75
1997M09	3.80	4.78	4.43	2.55	3.85	2.05	4.06	1.94	4.72
1997M10	4.34	5.32	5.10	3.29	4.35	2.69	4.56	2.56	4.94
1997M11	3.92	4.95	5.01	4.07	5.18	2.31	4.67	2.84	4.98
1997M12	3.97	4.80	4.91	3.82	4.65	2.39	4.69	2.88	4.93
1998M01	5.09	5.34	5.27	3.60	4.72	3.70	5.04	3.29	5.06
1998M02	4.18	4.56	4.25	3.22	4.53	2.62	4.80	2.99	4.72
1998M03	4.26	4.48	4.36	3.38	4.54	2.68	4.51	2.60	4.37
1998M04	4.55	3.83	3.83	3.28	3.92	4.01	4.43	3.74	4.26
1998M05	5.64	4.27	4.09	3.43	3.95	5.33	4.50	3.87	4.39
1998M06	6.44	4.94	4.84	3.41	3.84	6.29	4.86	4.33	4.52
1998M07	7.12	5.52	5.40	3.59	4.04	7.28	5.41	5.23	4.72
1998M08	6.60	5.37	5.26	3.67	3.45	6.66	5.55	5.40	4.84
1998M09	5.95	4.50	4.40	3.29	3.38	7.05	4.36	5.36	3.58
1998M10	6.57	4.75	4.56	2.74	2.87	7.80	4.36	5.37	3.68
1998M11	7.21	4.33	3.95	2.49	2.70	8.54	4.36	5.35	3.47

1998M12	6.38	4.22	3.88	1.90	2.87	7.55	4.51	5.52	3.67
1999M01	4.53	3.56	3.22	2.22	3.76	5.62	4.20	5.49	3.61
1999M02	5.46	4.74	4.70	2.52	3.95	5.93	4.88	5.34	4.62
1999M03	5.46	4.57	4.54	3.58	3.10	5.90	4.71	5.07	4.75
1999M04	4.03	3.02	2.96	1.60	2.81	4.36	2.93	3.09	3.14
1999M05	3.39	2.80	2.71	1.92	2.01	3.55	2.98	3.09	3.28
1999M06	2.53	2.46	2.35	1.25	2.15	2.45	2.45	2.33	2.93
1999M07	2.01	2.69	2.53	2.03	2.33	1.64	2.01	1.54	2.80
1999M08	2.85	2.70	2.52	2.15	4.02	2.54	2.14	1.60	3.01
1999M09	3.25	3.67	3.68	2.72	3.32	2.63	3.04	2.21	3.73
1999M10	3.40	4.07	3.92	3.18	4.46	1.94	4.04	2.33	4.89
1999M11	3.10	4.19	4.21	3.14	3.09	1.34	4.01	1.96	5.22
1999M12	2.82	3.96	3.88	3.05	4.36	1.00	3.51	1.36	4.72
2000M01	3.58	4.30	4.29	2.32	4.08	1.54	3.47	0.89	4.72
2000M02	3.48	3.59	3.65	3.41	4.93	1.89	3.08	1.00	4.09
2000M03	5.55	5.10	5.05	4.00	4.83	2.96	5.05	1.70	5.90
2000M04	6.58	5.34	5.45	4.22	4.45	2.92	6.85	2.30	7.69
2000M05	6.34	5.00	4.96	4.29	4.84	2.68	6.19	1.56	6.87
2000M06	6.48	4.94	4.67	3.60	4.83	2.85	6.40	1.81	6.90
2000M07	6.50	4.99	4.99	3.93	5.92	2.88	7.06	2.61	7.36
2000M08	6.06	4.84	4.88	4.20	6.86	2.36	7.20	2.75	7.59
2000M09	6.46	5.29	5.36	4.22	6.39	2.40	7.53	2.63	8.28
2000M10	7.52	6.24	6.34	6.12	6.29	2.72	8.69	2.88	9.33
2000M11	7.59	6.16	6.14	5.76	7.30	2.96	9.02	3.49	9.40
2000M12	7.89	6.58	6.67	5.61	7.12	3.52	8.84	3.58	9.22
2001M01	8.71	6.73	6.65	5.11	5.90	4.36	9.89	4.71	10.16
2001M02	8.34	7.04	7.05	5.89	5.86	3.88	9.61	4.30	9.96
2001M03	6.44	5.52	5.43	3.04	4.85	3.19	7.89	4.16	8.05
2001M04	5.41	5.92	5.82	4.93	4.50	3.29	6.37	3.96	6.40
2001M05	5.61	5.62	5.48	4.32	4.80	3.53	6.50	4.10	6.46
2001M06	5.39	5.48	5.41	3.43	5.42	3.38	6.27	3.97	6.10
2001M07	5.27	4.94	4.79	3.20	4.13	3.28	6.04	3.74	6.02
2001M08	5.44	5.11	4.81	3.32	1.71	3.19	5.86	3.14	5.86
2001M09	4.50	4.75	4.68	3.53	1.78	2.88	4.57	2.55	4.31
2001M10	2.94	2.38	2.19	0.89	1.96	2.38	2.79	2.03	2.60
2001M11	2.65	2.28	2.07	0.89	1.09	2.12	2.22	1.41	2.18
2001M12	2.71	2.29	2.19	1.65	1.37	2.13	2.18	1.29	2.14
2002M01	1.56	1.27	1.21	0.00	1.92	1.00	1.06	0.20	1.13
2002M02	1.42	1.67	1.58	0.00	1.35	1.30	0.82	0.49	0.75
2002M03	1.78	2.61	2.53	1.85	2.02	1.08	1.22	0.17	1.22
2002M04	1.55	1.98	1.93	1.24	3.64	1.09	1.33	0.68	1.32
2002M05	1.54	2.03	2.12	1.25	4.60	1.06	1.55	0.96	1.67
2002M06	2.43	3.02	3.16	3.19	3.95	1.78	2.55	1.75	2.78
2002M07	2.80	3.19	3.39	2.06	4.71	1.72	2.89	1.56	2.97
2002M08	3.33	3.69	3.77	3.51	2.61	2.87	3.41	2.85	3.27
2002M09	3.50	3.89	4.00	2.92	3.57	3.01	3.66	3.08	3.52
2002M10	2.96	3.22	3.29	2.33	3.57	2.56	3.25	2.84	3.08
2002M11	3.27	3.57	3.69	3.43	3.27	2.98	3.56	3.28	3.10
2002M12	3.15	3.68	3.81	3.52	4.01	2.86	3.92	3.80	3.13

2003M01	4.09	4.12	3.96	3.03	4.12	3.61	4.71	4.30	3.97
2003M02	5.23	4.99	4.57	3.04	6.42	4.67	5.92	5.42	5.05
2003M03	5.84	5.10	4.76	2.90	5.98	5.01	6.72	5.96	5.71
2003M04	6.47	6.22	6.10	3.98	4.87	5.49	7.46	6.53	6.47
2003M05	6.42	5.74	5.77	4.16	3.40	6.15	7.30	7.24	6.24
2003M06	5.22	4.60	4.52	3.69	3.15	5.20	5.64	5.75	4.71
2003M07	4.62	3.88	3.75	2.87	4.04	4.62	5.35	5.59	4.57
2003M08	3.88	3.69	3.67	2.44	3.78	3.61	4.88	4.85	4.49
2003M09	4.86	4.52	4.49	3.69	3.94	4.41	5.74	5.44	5.45
2003M10	5.15	4.40	4.30	3.69	3.80	5.10	5.75	5.88	5.34
2003M11	5.40	4.56	4.64	3.69	3.69	5.24	6.20	6.26	5.87
2003M12	5.82	5.16	5.10	3.39	4.07	5.34	6.63	6.28	6.51
2004M01	6.51	5.52	5.41	3.45	3.89	6.06	7.29	6.99	7.01
2004M02	6.13	5.13	5.14	3.60	2.85	5.81	7.16	7.11	6.95
2004M03	4.84	3.35	3.21	1.89	3.80	5.24	5.83	6.67	5.77
2004M04	4.54	3.29	3.29	2.85	3.87	4.80	5.18	5.71	5.25
2004M05	5.02	4.29	4.14	2.85	5.61	4.58	5.47	5.06	5.47
2004M06	6.75	5.09	4.73	3.05	5.62	6.02	7.91	7.35	7.70
2004M07	7.60	5.59	5.13	3.61	5.55	6.93	8.53	7.99	8.34
2004M08	8.49	6.44	6.09	4.82	5.34	7.58	9.16	8.23	8.77
2004M09	7.91	6.52	6.11	4.65	5.34	7.17	8.79	8.16	8.36
2004M10	7.30	5.97	5.64	4.29	5.35	6.33	8.20	7.28	8.14
2004M11	7.56	5.70	5.30	4.38	4.21	5.92	8.37	6.57	8.49
2004M12	6.74	5.68	5.14	3.86	3.98	5.33	7.50	5.99	7.83
2005M01	5.53	5.23	4.72	3.86	5.71	4.34	6.26	5.02	6.74
2005M02	5.03	5.58	5.02	3.69	5.34	3.61	5.52	3.93	6.19
2005M03	5.36	6.13	5.82	3.65	4.68	4.05	5.65	4.12	6.40
2005M04	5.94	6.22	5.96	4.03	5.87	4.56	6.35	4.76	7.04
2005M05	5.51	5.64	5.45	3.56	5.60	4.11	6.06	4.50	6.88
2005M06	4.34	6.05	5.99	5.34	5.51	2.73	4.60	2.68	5.54
2005M07	4.32	5.62	5.57	5.07	5.44	2.62	4.15	1.99	5.06
2005M08	3.65	5.24	5.12	3.59	4.11	2.29	3.67	1.99	4.45
2005M09	4.06	5.48	5.47	3.73	3.81	2.20	4.03	1.71	4.74
2005M10	4.71	5.24	5.17	3.81	3.97	3.03	4.74	2.66	5.08
2005M11	4.25	5.11	4.94	3.73	3.20	3.36	3.94	2.74	4.19
2005M12	4.52	4.86	4.66	3.73	4.29	3.61	4.10	2.81	4.42
2006M01	4.14	3.83	3.46	2.64	4.28	3.09	3.60	2.12	3.77
2006M02	4.07	4.06	3.99	3.21	4.08	2.85	3.72	2.09	3.89
2006M03	3.90	4.30	4.29	3.55	4.73	2.51	3.64	1.84	3.78
2006M04	3.88	4.04	3.95	3.19	4.73	2.67	3.73	2.17	3.75
2006M05	4.83	4.64	4.74	3.96	4.33	3.61	4.52	2.90	4.42
2006M06	5.16	4.40	4.46	3.43	4.40	4.11	4.59	3.08	4.53
2006M07	4.84	3.96	3.99	3.56	5.82	4.10	4.93	4.03	4.79
2006M08	5.16	4.31	4.26	3.69	5.52	4.30	5.14	4.07	5.01
2006M09	5.43	5.63	5.68	4.82	4.73	5.38	4.77	4.48	4.70
2006M10	5.51	5.54	5.66	5.02	4.51	5.62	4.92	4.84	4.86
2006M11	5.50	5.29	5.35	4.56	4.61	5.76	5.15	5.34	5.07
2006M12	5.69	4.84	4.67	3.01	5.19	6.28	5.15	5.69	4.78
2007M01	6.39	5.78	5.50	4.26	6.66	7.20	5.82	6.62	5.39

2007M02	6.37	5.53	5.38	4.08	6.58	7.71	5.65	7.05	4.96
2007M03	6.65	6.11	6.02	4.27	6.87	8.21	6.00	7.70	5.22
2007M04	6.29	6.05	6.17	4.28	4.66	7.82	5.59	7.24	4.74
2007M05	5.46	5.67	5.67	3.23	6.72	6.88	4.85	6.39	4.16
2007M06	4.50	5.19	5.14	3.78	4.82	6.08	4.35	6.28	3.62
2007M07	4.73	5.06	5.10	2.57	3.22	6.59	3.82	5.81	3.06
2007M08	4.15	4.37	4.36	2.35	3.07	5.96	3.36	5.33	2.74
2007M09	3.51	3.72	3.79	1.77	2.24	5.28	3.22	5.35	2.57
2007M10	3.12	3.06	3.15	1.37	4.29	4.48	3.16	4.88	2.60
2007M11	3.24	3.34	3.12	1.35	4.48	4.13	3.36	4.53	2.83
2007M12	3.82	4.57	4.52	3.65	6.75	4.08	4.09	4.51	3.63
2008M01	4.41	5.02	5.08	4.19	5.63	4.57	4.86	5.20	4.30
2008M02	5.21	5.53	5.74	4.78	6.78	5.31	5.56	5.81	4.61
2008M03	7.46	6.21	6.39	4.73	7.80	7.64	7.74	8.07	6.75
2008M04	7.99	6.71	7.00	5.11	8.35	8.26	8.44	8.94	7.73
2008M05	8.85	7.70	7.92	6.28	8.66	9.16	9.46	10.05	8.65
2008M06	11.83	10.34	9.52	6.89	9.49	10.60	12.95	11.79	12.20
2008M07	12.34	10.84	9.73	7.42	8.72	11.01	13.55	12.30	12.81
2008M08	12.84	11.18	10.10	6.84	8.87	11.64	13.97	12.85	13.27
2008M09	12.31	10.85	9.79	7.75	6.84	11.14	13.19	12.03	12.52
2008M10	11.11	10.50	9.94	8.01	6.83	10.32	11.34	10.42	10.76
2008M11	8.51	8.02	8.02	6.84	6.47	9.09	8.17	8.78	7.45
2008M12	6.19	5.76	5.73	3.29	3.32	7.97	5.50	7.49	4.74
2009M01	5.01	5.01	5.10	2.52	2.50	6.88	3.90	5.85	3.34
2009M02	3.53	3.58	3.46	1.67	6.78	5.45	2.46	4.48	2.52
2009M03	1.23	2.26	2.38	1.09	7.80	3.22	0.07	2.16	0.02
2009M04	1.36	1.98	2.07	1.02	8.35	3.27	0.04	1.97	-0.21

Cont...

WPIEX MOST15	WPIEX20	WPIEX25	WPI MBM5	WPI MBM10	WPI MBM15	WPI MBM20	WPI MBM25	WPI SDRP	WPISDRP DW	WPISD RPDWM
11.47	11.01	10.53	10.22	10.44	10.74	11.52	10.92	12.02	10.84	10.65
11.37	11.61	10.47	10.59	10.63	10.27	11.22	12.02	12.53	10.80	10.66
10.27	10.75	9.48	9.06	9.79	9.69	10.39	10.66	11.21	9.56	9.63
9.85	10.17	9.10	9.84	9.81	9.18	9.65	9.20	10.68	9.24	9.47
9.39	9.68	8.67	8.76	9.35	8.63	8.72	8.77	10.43	8.89	9.09
9.18	9.26	8.49	8.84	8.91	8.86	8.87	8.51	10.64	8.58	8.72
8.34	8.23	7.72	8.74	7.86	8.17	7.55	8.07	9.38	7.97	8.17
8.14	7.90	7.56	8.57	7.20	7.28	7.27	7.43	9.16	7.72	7.87
6.97	6.59	6.49	5.80	5.66	5.82	6.13	6.08	8.02	6.75	6.75
5.92	5.64	5.54	4.66	4.94	4.10	4.46	4.44	7.20	5.68	5.66
5.49	5.40	5.15	4.18	4.59	3.75	3.80	4.08	6.70	5.25	5.06
5.51	5.09	5.11	4.89	5.34	4.41	4.31	4.89	6.44	5.27	5.00
4.11	3.87	3.83	3.61	4.17	3.48	3.60	3.60	6.01	4.33	4.08
3.80	3.22	3.55	3.59	3.97	3.54	3.08	3.20	5.43	4.17	3.81
4.00	3.16	3.74	3.26	4.20	4.11	3.69	3.06	5.17	4.26	3.92
3.78	4.55	4.96	4.25	4.37	4.21	5.32	3.97	4.68	4.50	4.11

4.20	5.03	5.34	5.03	5.12	4.83	5.83	4.81	4.76	4.86	4.50
4.63	5.38	5.73	5.37	4.91	4.61	5.34	4.75	4.62	5.09	4.79
4.27	5.28	5.40	4.65	3.52	3.81	4.77	3.89	4.71	4.85	4.45
4.29	5.09	5.41	4.51	3.60	4.13	4.79	3.66	4.54	4.66	4.26
4.56	5.21	5.66	5.22	4.52	5.50	4.90	4.36	5.14	4.94	4.49
4.21	4.94	5.33	5.17	4.73	4.81	4.90	4.27	4.76	4.82	4.31
4.44	5.13	5.52	4.89	4.11	5.55	5.63	4.57	5.22	5.13	4.67
4.49	5.37	5.57	5.02	4.56	5.92	5.84	6.15	5.13	5.37	4.95
5.37	6.15	6.37	5.15	5.44	6.16	5.94	6.81	5.09	5.93	5.31
4.84	5.80	5.88	3.92	4.54	5.27	6.02	5.55	4.73	5.33	4.86
4.88	5.84	5.91	4.35	4.19	5.05	5.19	5.57	4.47	5.23	4.78
4.30	4.12	3.98	3.13	1.98	3.48	3.50	3.12	3.96	4.20	3.75
4.02	3.54	3.73	2.76	2.33	3.04	3.48	3.33	3.90	3.87	3.32
3.33	4.20	4.17	2.99	2.49	4.37	3.43	3.44	3.77	3.96	3.34
3.50	4.34	4.36	3.81	2.68	4.73	4.12	3.98	3.69	4.16	3.53
3.21	4.27	4.10	4.10	3.10	4.40	3.63	3.40	3.60	4.09	3.42
3.04	4.25	4.01	4.30	3.81	4.53	3.29	3.29	3.58	4.05	3.47
3.47	4.47	4.40	4.12	5.33	4.79	4.42	4.42	4.12	4.58	4.05
2.76	3.82	3.75	3.52	2.98	4.76	3.99	3.55	3.37	3.79	3.38
2.55	3.58	3.55	3.96	2.86	4.04	4.34	3.76	3.48	3.62	3.19
2.56	2.86	3.42	3.65	3.02	3.36	3.90	3.53	3.39	3.39	3.29
3.67	3.58	4.41	4.04	3.76	3.81	3.77	4.65	3.86	4.13	3.93
3.94	3.80	4.67	4.99	4.15	4.15	5.14	5.14	4.65	4.73	4.52
4.79	3.79	5.40	5.70	5.42	5.02	5.52	6.00	5.32	5.22	5.11
4.37	4.10	5.02	5.81	4.72	5.12	5.55	5.55	4.92	5.06	5.19
4.81	3.24	4.34	4.90	3.85	4.73	4.40	4.95	4.80	4.83	4.94
5.10	3.21	4.57	5.61	3.89	4.59	4.54	5.39	4.94	5.06	5.21
5.40	3.45	4.83	4.30	3.96	5.36	5.42	5.71	4.98	5.30	5.52
5.61	3.67	4.96	4.28	3.81	3.70	4.33	4.51	4.52	5.07	5.31
5.45	3.50	4.67	2.87	2.90	3.36	3.66	3.84	4.20	4.44	4.73
6.69	5.05	6.03	4.70	3.75	4.68	4.99	5.10	4.53	5.60	5.80
6.67	5.51	6.26	4.19	4.21	4.49	4.27	4.72	4.81	5.69	5.80
4.98	4.68	4.87	2.95	2.77	2.17	1.95	2.99	4.03	4.37	4.43
3.95	4.47	3.97	2.52	2.10	2.27	2.72	3.63	3.91	3.92	4.06
3.74	4.76	3.84	2.26	1.97	1.75	2.16	3.11	3.15	3.53	3.66
3.44	5.06	3.58	1.27	2.66	1.50	3.17	2.68	2.73	3.45	3.47
4.14	5.18	4.24	1.20	2.72	2.57	2.24	3.29	3.00	3.86	3.77
4.60	5.65	5.00	2.73	3.12	2.36	4.06	4.06	3.22	4.19	4.20
4.52	6.63	5.77	2.88	2.20	4.40	4.59	4.59	3.01	4.38	4.46
4.18	6.75	5.71	2.93	3.24	4.46	4.39	4.39	2.90	4.22	4.17
3.40	6.05	4.99	3.02	2.97	3.66	3.73	3.67	2.46	3.72	3.61
3.19	6.06	4.95	4.00	3.69	3.62	3.21	3.58	2.28	3.84	3.55
2.64	5.11	4.21	3.20	2.68	2.85	2.44	3.80	2.44	3.31	2.95
4.48	7.12	6.19	4.88	4.95	4.17	4.13	5.63	2.75	5.59	4.88
4.83	8.78	7.71	5.26	5.19	4.67	4.67	3.89	2.99	6.48	5.90
4.98	8.73	7.82	4.57	5.02	4.47	4.41	3.65	2.72	6.38	5.73
4.85	8.46	7.69	4.22	4.65	4.42	4.36	3.80	2.82	6.31	5.64
4.79	8.14	7.64	5.42	4.60	4.54	3.84	3.83	2.86	6.18	5.68
4.55	8.10	7.39	4.92	4.59	4.12	3.41	3.40	2.84	6.01	5.46

4.86	8.80	7.75	5.03	4.70	4.38	3.81	3.73	3.03	6.58	5.79
5.00	10.05	8.82	6.66	6.28	4.64	4.05	3.98	3.26	7.40	6.60
5.09	9.73	8.71	6.92	4.68	4.73	4.21	4.12	3.60	7.43	6.73
5.21	9.62	8.69	7.19	4.87	5.28	4.88	4.80	3.88	7.52	6.85
6.23	10.47	9.59	7.72	4.66	6.06	5.56	5.55	4.80	8.41	7.75
6.05	10.13	9.25	8.34	5.31	5.51	5.32	8.21	4.78	8.20	7.49
4.69	7.78	7.28	5.52	4.91	4.10	3.99	6.32	4.59	6.08	5.81
4.51	6.55	5.89	4.83	5.21	5.64	5.54	5.50	4.40	5.51	5.13
4.32	6.03	5.72	4.69	4.52	4.81	5.51	5.70	4.40	5.30	5.02
3.89	5.37	5.22	4.91	4.92	3.70	5.18	5.01	4.22	4.92	4.73
3.41	5.32	4.76	4.46	4.71	4.58	4.70	4.66	3.96	4.77	4.55
3.70	5.47	5.00	4.19	3.24	5.16	4.86	4.82	3.92	5.05	4.66
3.30	4.17	4.26	4.10	3.56	4.29	3.85	3.82	3.64	4.15	3.79
3.72	2.65	2.91	1.71	1.42	1.30	2.65	2.65	3.45	3.45	2.91
3.38	2.38	2.59	1.52	1.26	1.01	2.16	2.33	3.05	3.23	2.62
3.47	2.45	2.63	2.17	1.54	0.94	2.25	2.08	3.17	3.41	2.72
2.26	1.43	1.49	0.74	0.10	-0.15	0.91	1.49	2.00	2.36	1.74
2.08	1.15	1.39	1.08	0.62	1.58	1.66	1.55	1.79	2.16	1.70
1.81	1.82	1.91	1.99	1.60	2.17	2.20	2.20	1.40	2.31	1.78
1.35	1.28	1.41	1.39	1.82	1.56	1.48	1.72	1.61	1.93	1.52
1.44	1.51	1.52	1.53	1.86	1.34	1.33	1.60	1.61	1.96	1.57
1.99	2.35	2.37	2.71	2.48	2.02	2.09	2.59	2.07	2.60	2.24
2.27	2.89	2.73	2.70	2.51	2.46	2.49	2.59	2.32	2.99	2.54
2.61	3.01	2.98	3.42	3.03	2.70	2.88	2.85	2.79	3.11	2.89
2.66	3.31	3.08	4.27	3.19	2.64	2.61	3.04	2.90	3.22	3.09
1.96	2.83	2.60	3.34	2.81	2.12	2.15	2.19	2.56	2.57	2.57
2.52	3.21	3.03	3.13	3.04	3.04	2.16	2.45	2.78	2.91	2.94
2.88	3.47	3.31	3.06	3.25	3.17	2.65	2.74	2.74	3.06	3.13
3.11	4.14	3.90	3.25	3.66	3.77	3.11	3.79	3.39	3.50	3.61
3.62	4.90	4.69	3.92	4.18	4.79	4.38	4.67	4.04	4.11	4.30
3.65	5.07	5.01	4.35	4.83	5.04	4.33	5.35	3.90	4.25	4.60
4.39	5.52	5.58	5.49	6.05	5.62	4.92	6.02	4.05	4.82	5.14
4.85	5.11	5.35	6.42	4.65	5.29	4.56	5.62	4.34	4.85	5.15
4.33	4.15	4.39	4.33	3.44	3.35	4.71	5.24	3.56	4.10	4.29
3.91	3.78	4.02	3.51	3.09	2.91	3.93	4.33	3.25	3.63	3.91
3.75	3.89	3.96	3.23	3.35	3.39	3.69	3.69	2.77	3.31	3.50
4.34	4.74	4.70	4.77	3.95	4.10	4.07	3.76	3.18	3.97	4.09
4.45	4.48	4.57	4.32	3.79	4.09	4.03	4.03	3.24	4.01	4.22
4.96	5.01	5.13	5.03	3.91	3.99	4.16	4.14	3.23	4.19	4.41
4.59	5.19	5.19	4.21	4.22	4.16	4.78	4.78	3.20	4.24	4.54
5.16	5.74	5.80	5.43	4.72	4.59	4.95	5.30	3.32	4.70	5.08
5.37	5.49	5.78	5.56	4.18	4.75	4.69	5.21	3.24	4.62	5.02
5.13	4.64	4.58	3.46	2.89	3.29	3.34	3.80	3.46	4.21	4.43
4.69	4.53	4.44	3.40	2.36	3.23	3.41	3.31	3.37	3.88	4.02
4.64	5.04	5.10	3.68	3.51	3.45	3.77	4.69	3.44	4.14	4.24
5.93	7.16	6.80	5.08	5.29	4.67	4.67	4.94	4.61	5.25	5.46
7.02	7.91	7.83	4.71	5.46	5.48	5.56	5.80	5.36	6.19	6.31
6.94	8.02	8.17	5.79	6.45	6.65	6.87	8.05	5.92	6.60	6.81
6.39	7.22	7.55	5.37	6.38	6.43	7.28	7.30	5.77	6.21	6.49

6.08	7.28	7.37	4.68	6.29	5.87	6.70	6.72	5.57	5.93	6.13
5.61	7.62	7.65	5.35	4.10	6.93	6.96	6.98	5.54	6.08	6.27
5.52	7.07	7.18	3.80	6.26	6.54	6.18	6.20	5.45	5.69	5.87
5.21	5.89	6.35	3.69	4.82	4.51	5.53	5.14	5.18	5.08	5.16
4.59	5.82	5.88	3.48	5.14	5.88	5.98	4.71	4.86	4.76	4.70
4.84	5.96	6.15	4.13	5.82	5.79	6.32	5.11	4.90	4.73	4.76
5.51	6.85	6.93	4.18	3.98	6.40	6.47	5.69	5.05	5.25	5.34
5.12	6.72	6.51	3.45	4.38	5.80	5.05	5.31	4.69	5.02	5.09
4.43	5.52	5.50	4.55	4.93	5.58	5.59	4.67	4.01	4.60	4.49
3.75	5.17	5.23	4.68	4.48	5.55	5.83	4.67	3.63	4.16	4.06
3.52	4.64	4.59	3.52	3.78	4.95	4.72	4.61	3.50	3.72	3.54
3.32	5.28	4.97	3.40	4.62	5.43	5.43	4.40	3.27	3.84	3.67
3.64	5.58	5.43	3.78	4.66	4.36	5.24	4.62	3.90	4.13	4.05
3.44	4.47	4.43	3.22	4.91	4.83	4.39	4.14	4.00	3.58	3.51
3.27	4.76	4.38	3.68	4.80	4.42	4.52	4.06	4.07	3.65	3.55
2.51	4.38	3.84	3.22	1.98	3.38	3.90	3.60	3.62	3.32	3.25
2.82	4.44	4.11	3.50	2.98	3.51	3.85	3.73	3.45	3.52	3.52
2.72	4.45	4.13	3.71	3.25	4.50	3.50	3.49	3.52	3.45	3.47
2.81	4.34	4.05	3.38	4.23	3.29	3.47	3.40	3.41	3.35	3.44
3.64	5.14	4.99	4.40	3.39	3.67	4.01	4.00	3.95	4.16	4.28
3.26	5.18	5.03	5.24	3.33	3.98	4.23	4.69	4.19	4.20	4.38
3.43	5.12	4.83	4.03	2.77	3.67	3.80	3.84	4.21	4.00	4.32
3.61	5.47	5.15	4.44	2.82	4.32	4.45	4.54	3.94	4.23	4.66
4.99	5.33	5.34	5.55	4.74	4.43	4.55	4.94	4.73	4.83	5.12
5.53	5.47	5.47	5.69	4.64	4.51	4.68	4.93	4.85	5.23	5.54
5.62	5.46	5.43	5.03	4.70	4.62	4.51	4.51	4.86	5.30	5.69
6.07	5.22	5.61	4.50	4.35	4.26	5.08	4.90	5.03	5.37	5.85
6.67	5.89	6.15	5.17	5.74	5.84	5.19	5.85	5.34	5.79	6.27
6.37	5.54	5.64	5.44	4.51	5.83	6.04	5.41	5.43	5.56	6.04
6.46	5.64	5.63	6.74	5.21	5.83	5.92	5.85	5.60	5.76	6.22
5.96	5.22	5.13	5.93	5.13	5.52	5.59	5.14	5.56	5.62	6.04
5.34	4.78	4.49	4.58	4.36	5.35	5.35	5.59	5.20	4.99	5.35
4.87	4.16	3.71	3.99	3.83	4.65	4.86	4.86	4.58	4.27	4.76
4.99	3.76	3.62	4.74	3.51	4.36	4.36	4.15	4.71	4.46	4.82
4.53	3.41	3.13	3.86	4.38	3.65	3.65	2.90	4.68	4.14	4.41
3.75	3.12	2.68	2.69	2.64	3.10	3.30	2.63	3.98	3.46	3.85
3.32	3.08	2.57	2.74	2.03	3.01	2.96	2.24	3.52	3.18	3.54
3.10	3.47	2.81	2.00	2.60	3.48	3.21	3.50	3.46	3.38	3.66
2.97	4.02	3.23	3.43	4.22	4.04	4.15	3.40	3.69	3.83	4.00
3.37	4.31	3.68	4.49	4.51	5.18	3.43	3.64	4.19	4.15	4.39
3.73	4.59	4.15	5.61	5.14	4.90	4.20	4.20	4.68	4.43	4.68
5.96	6.53	6.37	6.90	5.21	5.74	5.43	7.05	5.61	5.85	6.30
6.89	7.48	7.21	7.22	6.08	5.32	5.62	7.24	6.37	6.57	7.05
7.39	7.93	7.83	8.49	6.35	6.41	6.37	7.58	7.14	7.31	7.75
8.30	10.88	10.66	8.77	6.57	9.71	10.50	10.86	8.21	9.21	9.81
8.83	11.47	11.33	8.75	6.71	9.83	11.02	11.36	8.50	9.60	10.20
9.54	11.79	11.95	9.62	7.42	10.33	11.51	11.85	8.86	9.98	10.54
9.06	11.26	11.36	9.93	7.31	9.74	11.06	11.37	8.99	9.74	10.20
8.61	10.19	10.37	9.34	8.45	9.61	10.47	10.76	8.32	8.89	9.32

7.83	7.40	7.89	8.05	6.94	7.26	7.71	7.96	7.47	7.23	7.55
7.20	5.25	5.88	5.29	4.30	4.99	5.50	5.51	6.45	5.62	5.81
5.70	3.52	4.37	5.10	4.79	4.35	4.43	4.55	5.81	4.68	4.71
4.84	2.40	3.23	2.75	3.24	2.72	2.66	3.40	4.86	3.90	3.87
2.34	-0.01	0.79	1.10	2.24	0.91	0.47	1.03	3.69	2.12	2.00
1.69	-0.81	0.35	1.81	0.55	1.23	1.23	1.16	3.15	1.61	1.53

Cont.....

WPI SDRPM	WPI SDS	WPI SDSDW	WPI SDSDWM	WPI SDSM	WPIPW	WPIPDW	WPIES (g=0.105)	WPIES (g=0.125)	HP (14000)
12.00	11.91	10.78	10.37	11.69	12.67	9.74	5.27	5.27	8.47
12.60	12.41	10.73	10.41	12.29	13.37	9.47	5.87	5.99	8.28
11.62	11.11	9.47	9.44	11.39	12.91	9.01	6.40	6.60	8.08
11.30	10.59	9.15	9.31	11.09	12.92	9.57	6.75	7.00	7.89
10.99	10.36	8.83	9.03	10.87	12.21	9.09	7.06	7.33	7.69
11.18	10.58	8.51	8.64	11.03	12.21	8.47	7.26	7.53	7.50
10.05	9.32	7.90	8.09	9.91	10.98	8.08	7.44	7.71	7.31
9.81	9.10	7.67	7.83	9.69	10.86	8.01	7.56	7.82	7.12
8.55	8.00	6.73	6.85	8.53	9.13	6.34	7.64	7.88	6.94
7.66	7.17	5.66	5.84	7.67	7.98	5.10	7.54	7.74	6.76
7.00	6.68	5.25	5.25	7.03	7.01	4.03	7.29	7.41	6.58
6.65	6.42	5.27	5.22	6.68	6.51	3.79	7.00	7.06	6.42
6.20	6.00	4.36	4.43	6.28	6.17	2.97	6.75	6.75	6.26
5.49	5.44	4.22	4.13	5.58	5.25	2.58	6.44	6.38	6.11
5.26	5.19	4.31	4.26	5.36	5.00	2.82	6.15	6.05	5.96
4.72	4.69	4.50	4.33	4.84	3.97	2.35	5.89	5.75	5.83
4.79	4.76	4.84	4.65	4.86	3.93	2.81	5.72	5.57	5.71
4.59	4.61	5.06	4.93	4.66	3.65	3.35	5.64	5.48	5.59
4.50	4.73	4.85	4.65	4.64	2.89	2.43	5.58	5.43	5.48
4.28	4.56	4.65	4.43	4.41	2.37	2.26	5.46	5.31	5.38
4.76	5.15	4.92	4.61	4.89	2.61	2.57	5.35	5.20	5.29
4.27	4.78	4.80	4.44	4.42	1.79	2.00	5.33	5.20	5.21
4.74	5.23	5.12	4.80	4.87	2.06	2.33	5.31	5.19	5.13
4.70	5.17	5.39	5.04	4.84	2.20	2.97	5.32	5.22	5.06
4.62	5.13	5.91	5.23	4.71	1.98	2.98	5.33	5.24	5.00
4.36	4.76	5.30	4.78	4.46	1.99	3.06	5.38	5.31	4.95
4.10	4.50	5.20	4.66	4.18	1.89	3.51	5.34	5.27	4.90
3.58	4.00	4.20	3.74	3.71	1.46	2.37	5.30	5.24	4.86
3.53	3.93	3.86	3.30	3.62	1.79	1.86	5.12	5.02	4.82
3.38	3.79	3.92	3.25	3.45	1.59	1.63	4.92	4.80	4.79
3.31	3.67	4.10	3.37	3.31	1.97	2.05	4.80	4.67	4.77
3.26	3.60	4.04	3.28	3.26	2.24	1.73	4.75	4.63	4.75
3.47	3.58	4.02	3.29	3.39	3.85	2.06	4.66	4.54	4.74
4.13	4.11	4.56	3.81	3.98	5.06	2.93	4.59	4.47	4.73
3.50	3.36	3.76	3.13	3.35	4.55	2.56	4.64	4.55	4.73
3.61	3.45	3.56	2.92	3.44	4.27	2.06	4.59	4.50	4.72
3.67	3.37	3.37	3.11	3.53	4.99	3.78	4.56	4.47	4.72
3.97	3.83	4.10	3.72	3.83	4.86	3.98	4.56	4.48	4.73

4.73	4.60	4.69	4.30	4.57	5.65	4.39	4.67	4.63	4.73
5.41	5.27	5.20	4.86	5.19	6.73	5.93	4.86	4.85	4.74
5.21	4.89	5.05	4.98	5.03	6.79	6.30	5.09	5.14	4.74
5.05	4.78	4.85	4.82	4.91	6.51	6.02	5.25	5.32	4.74
5.18	4.92	5.08	5.04	5.00	6.60	6.50	5.33	5.40	4.75
5.27	4.95	5.31	5.31	5.06	6.65	7.05	5.46	5.54	4.75
4.71	4.49	5.06	5.12	4.57	5.04	6.65	5.64	5.75	4.76
4.41	4.19	4.44	4.63	4.36	4.59	6.08	5.72	5.83	4.76
4.68	4.51	5.59	5.66	4.65	4.58	6.59	5.59	5.67	4.77
4.83	4.78	5.68	5.71	4.85	4.73	6.33	5.58	5.64	4.77
3.96	4.00	4.38	4.38	3.98	3.47	4.09	5.57	5.62	4.78
3.95	3.89	3.94	4.05	3.97	3.55	3.70	5.40	5.42	4.78
3.25	3.14	3.56	3.70	3.31	2.77	2.92	5.19	5.17	4.79
2.84	2.74	3.49	3.53	2.94	2.07	2.18	4.91	4.84	4.80
2.95	3.01	3.90	3.79	3.03	1.74	2.39	4.61	4.48	4.82
3.24	3.22	4.22	4.18	3.29	2.33	3.17	4.42	4.28	4.83
3.06	3.00	4.38	4.39	3.14	2.13	3.52	4.30	4.15	4.85
2.82	2.89	4.20	4.11	2.93	1.49	2.91	4.21	4.06	4.87
2.34	2.46	3.70	3.59	2.48	0.83	2.23	4.09	3.94	4.88
2.05	2.27	3.80	3.50	2.17	0.29	1.76	3.96	3.80	4.90
2.17	2.42	3.28	2.92	2.24	0.57	1.32	3.92	3.77	4.92
2.42	2.77	5.56	4.59	2.41	0.38	2.22	3.87	3.73	4.94
2.74	3.00	6.43	5.51	2.71	1.01	3.47	4.05	3.96	4.96
2.44	2.74	6.33	5.35	2.41	0.89	3.04	4.31	4.29	4.97
2.46	2.82	6.23	5.24	2.41	0.88	2.83	4.53	4.54	4.98
2.62	2.86	6.09	5.33	2.59	1.61	3.50	4.73	4.79	4.99
2.59	2.84	5.92	5.12	2.58	1.61	3.22	4.92	5.00	4.99
2.58	3.03	6.47	5.47	2.62	0.90	2.83	5.04	5.13	4.98
2.81	3.25	7.27	6.18	2.81	1.13	3.23	5.19	5.30	4.97
3.20	3.58	7.30	6.32	3.17	1.77	3.67	5.43	5.58	4.96
3.49	3.86	7.40	6.45	3.45	2.45	4.00	5.66	5.83	4.93
4.40	4.75	8.27	7.37	4.34	3.43	4.80	5.89	6.09	4.91
4.32	4.73	8.06	7.15	4.27	3.17	4.26	6.19	6.41	4.87
4.30	4.54	5.94	5.67	4.31	3.57	3.92	6.41	6.65	4.83
4.08	4.37	5.41	5.10	4.12	3.26	3.08	6.42	6.63	4.79
4.08	4.35	5.19	4.97	4.11	3.31	3.48	6.31	6.47	4.75
3.96	4.17	4.80	4.68	3.99	3.31	3.63	6.24	6.37	4.70
3.69	3.92	4.65	4.43	3.69	2.74	3.25	6.15	6.24	4.65
3.53	3.87	4.92	4.49	3.51	2.30	2.74	6.06	6.12	4.60
3.29	3.60	4.05	3.66	3.24	2.37	2.12	5.99	6.04	4.55
3.04	3.42	3.37	2.93	3.04	1.83	0.96	5.83	5.84	4.51
2.60	3.03	3.18	2.68	2.64	1.14	0.34	5.53	5.48	4.46
2.68	3.15	3.36	2.78	2.72	0.79	0.07	5.23	5.13	4.43
1.56	1.99	2.34	1.77	1.62	-0.42	-0.78	4.96	4.82	4.39
1.47	1.79	2.15	1.73	1.52	-0.08	-0.23	4.61	4.42	4.37
0.96	1.37	2.28	1.78	0.99	-0.64	-0.41	4.27	4.04	4.35
1.18	1.58	1.90	1.52	1.20	-0.18	-0.31	4.01	3.76	4.33
1.25	1.59	1.93	1.55	1.25	0.07	-0.11	3.75	3.48	4.33
1.69	2.04	2.56	2.15	1.65	0.46	0.54	3.52	3.24	4.33

1.95	2.29	2.93	2.36	1.87	0.64	0.45	3.40	3.14	4.34
2.51	2.75	3.06	2.70	2.39	1.63	1.77	3.34	3.10	4.35
2.72	2.86	3.17	2.86	2.59	2.06	2.16	3.34	3.13	4.38
2.43	2.53	2.53	2.34	2.31	2.09	2.09	3.36	3.17	4.41
2.69	2.74	2.86	2.65	2.53	2.54	2.61	3.32	3.15	4.44
2.67	2.69	2.99	2.81	2.49	2.63	2.93	3.31	3.16	4.48
3.31	3.33	3.42	3.24	3.08	3.46	3.60	3.29	3.16	4.52
4.00	3.97	4.00	3.85	3.71	4.40	4.71	3.38	3.28	4.57
4.08	3.83	4.11	4.08	3.76	5.38	5.82	3.57	3.52	4.62
4.27	3.97	4.66	4.60	3.95	5.51	6.37	3.81	3.81	4.67
4.52	4.25	4.71	4.67	4.20	5.43	6.29	4.09	4.14	4.72
3.73	3.48	3.99	3.89	3.46	4.55	5.14	4.33	4.43	4.78
3.45	3.20	3.54	3.61	3.25	4.31	5.16	4.43	4.53	4.83
2.95	2.73	3.24	3.23	2.79	3.58	4.51	4.45	4.54	4.88
3.30	3.14	3.87	3.74	3.11	3.74	4.88	4.39	4.46	4.94
3.44	3.20	3.92	3.87	3.23	4.02	5.39	4.44	4.51	4.99
3.43	3.19	4.10	4.05	3.21	4.20	6.01	4.51	4.59	5.04
3.53	3.17	4.15	4.14	3.30	4.64	6.35	4.61	4.69	5.08
3.72	3.28	4.60	4.64	3.47	5.03	7.12	4.73	4.83	5.13
3.66	3.22	4.55	4.63	3.43	5.12	7.50	4.92	5.04	5.17
3.79	3.44	4.19	4.20	3.62	4.75	6.14	5.05	5.18	5.21
3.64	3.35	3.85	3.82	3.48	4.28	5.27	5.02	5.13	5.24
3.68	3.42	4.10	3.99	3.53	4.63	5.51	4.97	5.06	5.27
5.01	4.57	5.18	5.09	4.76	6.95	7.04	4.98	5.05	5.30
5.68	5.29	6.11	5.99	5.42	7.41	7.53	5.16	5.27	5.32
6.23	5.83	6.50	6.54	5.97	8.23	8.14	5.42	5.56	5.34
6.11	5.68	6.14	6.33	5.86	8.61	8.29	5.74	5.92	5.35
5.83	5.48	5.87	6.03	5.62	7.89	7.41	5.97	6.17	5.35
5.79	5.46	6.01	6.14	5.60	7.48	6.96	6.11	6.31	5.36
5.63	5.38	5.64	5.85	5.51	7.01	6.48	6.26	6.47	5.35
5.30	5.13	5.06	5.25	5.26	6.41	5.85	6.31	6.50	5.35
4.87	4.81	4.73	4.83	4.86	5.42	4.43	6.23	6.38	5.34
4.93	4.84	4.68	4.86	4.89	5.54	4.87	6.10	6.21	5.33
5.09	4.98	5.19	5.40	5.04	5.87	5.63	6.03	6.11	5.31
4.75	4.63	4.97	5.19	4.72	5.31	5.04	6.02	6.09	5.30
3.91	3.97	4.55	4.66	3.97	3.53	3.79	5.96	6.01	5.29
3.54	3.59	4.09	4.12	3.57	3.40	3.52	5.79	5.80	5.27
3.40	3.48	3.67	3.60	3.44	3.33	2.82	5.64	5.62	5.26
3.24	3.24	3.76	3.66	3.28	3.21	2.67	5.43	5.37	5.25
3.91	3.86	4.05	3.97	3.87	4.64	3.63	5.29	5.21	5.24
4.02	3.96	3.52	3.44	3.94	5.11	3.51	5.23	5.15	5.24
4.10	4.03	3.58	3.47	4.00	5.37	3.47	5.12	5.03	5.24
3.65	3.57	3.26	3.20	3.56	5.14	3.11	5.06	4.97	5.24
3.54	3.41	3.46	3.46	3.47	5.29	3.86	4.96	4.87	5.24
3.57	3.49	3.40	3.39	3.52	5.01	3.70	4.87	4.77	5.25
3.60	3.38	3.29	3.31	3.52	5.58	4.05	4.77	4.66	5.27
4.21	3.91	4.09	4.08	4.10	6.57	5.29	4.67	4.56	5.28
4.47	4.15	4.17	4.21	4.35	6.93	5.68	4.69	4.59	5.30
4.59	4.15	3.95	4.18	4.47	7.25	5.95	4.74	4.66	5.33

4.38	3.87	4.17	4.49	4.25	7.06	6.58	4.75	4.69	5.36
5.03	4.66	4.79	4.95	4.87	7.38	6.84	4.79	4.75	5.39
5.22	4.79	5.20	5.40	5.07	7.31	7.02	4.86	4.83	5.42
5.30	4.81	5.27	5.60	5.18	7.44	7.29	4.93	4.92	5.46
5.49	4.96	5.33	5.74	5.35	7.56	7.65	4.99	4.99	5.50
5.80	5.26	5.73	6.08	5.61	7.58	7.69	5.06	5.08	5.55
5.90	5.35	5.52	5.87	5.70	7.55	7.08	5.20	5.24	5.59
6.05	5.52	5.71	6.06	5.85	7.57	7.08	5.32	5.38	5.64
5.93	5.51	5.60	5.93	5.77	6.82	6.49	5.46	5.54	5.69
5.45	5.16	4.98	5.29	5.35	5.50	5.07	5.55	5.63	5.75
4.93	4.55	4.27	4.73	4.86	5.02	4.68	5.54	5.61	5.80
4.94	4.70	4.49	4.80	4.88	4.85	4.53	5.43	5.47	5.86
4.90	4.68	4.18	4.41	4.85	4.52	3.83	5.36	5.38	5.92
4.26	3.99	3.51	3.89	4.24	3.79	3.54	5.23	5.23	5.99
3.78	3.54	3.22	3.57	3.80	3.10	3.21	5.05	5.01	6.05
3.68	3.49	3.42	3.66	3.71	2.66	2.85	4.85	4.78	6.12
3.84	3.72	3.88	4.00	3.90	2.68	2.92	4.68	4.58	6.19
4.47	4.22	4.18	4.36	4.51	3.88	3.87	4.59	4.49	6.26
5.04	4.69	4.44	4.58	5.01	5.33	4.58	4.57	4.48	6.33
6.21	5.59	5.82	5.94	5.98	7.38	7.02	4.64	4.57	6.39
7.05	6.35	6.55	6.77	6.84	8.58	7.91	4.93	4.93	6.46
7.82	7.12	7.29	7.44	7.57	9.77	8.87	5.26	5.31	6.52
8.96	8.17	9.11	9.23	8.58	11.41	11.50	5.63	5.76	6.57
9.23	8.44	9.49	9.57	8.81	11.83	12.06	6.28	6.52	6.62
9.57	8.81	9.87	9.90	9.14	12.45	12.80	6.92	7.24	6.66
9.63	8.95	9.64	9.61	9.24	12.13	12.12	7.54	7.94	6.70
8.93	8.31	8.83	8.88	8.61	11.23	10.97	8.04	8.49	6.73
7.97	7.50	7.25	7.38	7.78	9.90	9.13	8.36	8.82	6.75
6.86	6.53	5.70	5.72	6.73	8.41	7.12	8.38	8.78	6.77
5.99	5.92	4.80	4.71	5.91	6.65	5.50	8.15	8.46	6.79
4.88	5.00	4.05	4.01	4.92	4.44	4.43	7.82	8.02	6.80
3.65	3.85	2.32	2.37	3.83	3.30	2.36	7.37	7.46	6.81
3.08	3.28	1.78	1.77	3.20	2.86	2.42	6.72	6.68	6.83

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