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Understanding Inflation in India§

ABSTRACT This paper examines the behavior of quarterly inflation in India since 1994, both headline inflation and core inflation, as measured by the weighted median of price changes across industries. We explain core inflation with a Phillips curve in which the inflation rate depends on a slow-moving average of past inflation and on the deviation of output from its long-run trend. Headline inflation is more volatile than core: it fluctuates due to large changes in the relative prices of certain industries, which are largely but not exclusively industries that produce food and energy. There is some evidence that changes in headline inflation feed into expected inflation and future core inflation. Several aspects of India's inflation process are similar to inflation in advanced economies in the 1970s and 1980s.

Keywords: *Inflation, Phillips Curve, India*

JEL Classification: *E31, E37, E52*

1. Introduction

"Inflation poses a serious threat to the growth momentum. Whatever be the cause, the fact remains that inflation is something which needs to be tackled with great urgency …"

[Dr Manmohan Singh, Then Prime Minister of India, February 4, 2011, New Delhi]

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Over the last decade, inflation has emerged as a leading concern for India's economic policymakers and citizens. Worries grew as the inflation rate (measured as the 12-month change in the consumer price index [CPI]) rose from 3.7 percent to 12.1 percent over 2001–10. The inflation rate fell to 5.2 percent in early 2015, leading to a debate about whether this moderation was likely to endure or inflation would rise again.

What explains the movements in India's inflation rate? Economists, policymakers, and journalists have proposed a variety of answers to this question. Many emphasize the effects of rises and falls in food price inflation, especially for certain staples such as pulses, milk, fruits, and vegetables.[1] These price increases are, in turn, explained by factors including shifting dietary patterns, rising rural wages, and a myriad of government policies such as price supports and the rural unemployment guarantee scheme (Rajan 2014). Some suggest that the monetary and fiscal stimulus following the 2008 financial crisis led to higher inflation, while others cite supply side constraints arising from policy bottlenecks (Government of India 2014).

Many, including the Reserve Bank of India (RBI) Governor, Raghuram Rajan, fear that high levels of inflation may become embedded in the expectations of price setters, creating a self-sustaining "inflationary spiral" (Rajan 2014). The role of monetary policy is controversial, with media reports and analysts debating the role of interest rate increases in explaining the recent fall in inflation, and more generally the RBI's ability to control inflation and the effects on the real economy (Bhalla 2014a and 2014b; Lahiri 2014).

The debates about inflation in India are reminiscent of debates that have been going on for decades in advanced economies, especially debates about the 1970s and 1980s, when inflation in the United States and Europe reached double-digit rates, similar to the inflation rate in India more recently. These debates have spurred a large body of research on inflation, especially in the United States. We draw on this literature to explore inflation in India. One broad theme is that, despite the differences between the Indian and US economies, the factors driving inflation fluctuations are similar in many respects.

Section 2 of this paper explores a central issue in discussions of inflation: the distinction between headline and core inflation. Core inflation captures the underlying trend in inflation, and headline inflation fluctuates around core because of large changes in the relative prices of certain

1. Gokarn (2011), for example, analyzes the microlevel price dynamics of the major dietary sources of protein in India.

goods—price changes that are often called "supply shocks." We follow an approach to measuring core inflation developed by the Federal Reserve Bank of Cleveland: core inflation is measured by the weighted median of price changes across industries. To implement this approach for India, we examine the inflation rate in the wholesale price index (WPI). WPI inflation is highly disaggregated by sector, allowing us to compute a historical series for median inflation.

We find that weighted median inflation is substantially less volatile at the quarterly frequency than headline inflation, a result that researchers have found for many other countries. We also have a finding that is not typical of other countries: the average level of median inflation (about 3.4 percent per year since 1994) is substantially lower than the average level of headline inflation (5.6 percent). This difference arises because the distribution of price changes across industries is often skewed to the right—there is a tail of large price increases that raise headline inflation, but are filtered out of the median—and the distribution is rarely skewed to the left. Many of the large price increases that raise headline WPI inflation—but far from all of them—occur for different types of food products and fuels. The role of food prices is consistent with the common view that these prices strongly influence aggregate inflation.

Section 3 explores the determinants of core inflation. We estimate a version of a standard inflation equation in textbooks and in a large body of empirical research, a Phillips curve. In this equation, core inflation at the quarterly frequency depends on expected inflation, which is determined by past levels of inflation, and by the level of economic activity, as captured by the deviation of output from its long-run trend. Our estimates of the Phillips curve are somewhat imprecise compared to estimates for advanced economies, reflecting the fact that the necessary data are available only since 1996, and that they are noisy, with substantial quarter-to-quarter movements in weighted median inflation. Nonetheless, the data point to the following two conclusions about India's Phillips curve.

First, current core inflation depends on many lags of past inflation with weights that decline slowly. We interpret this finding as reflecting the slow adjustment of expected inflation. In particular, we estimate that a one-percentage-point deviation of inflation from its expected level changes expected inflation in the next quarter by only 0.1 percentage points. This inertia in expectations is consistent with the view that, once a high level of inflation becomes embedded in expectations, it is not easy to reduce.

Second, for a given level of expected inflation, there is a positive relationship between inflation and the deviation of output from its long-run trend. This effect is central to the textbook Phillips curve, but some previous work has questioned it for India.[2] Along with our finding about the slow adjustment of expectations, the estimated effect of output implies that the monetary policy can reduce inflation, but with a short-run cost in output. In particular, we estimate a sacrifice ratio—the loss in percentage points of annual output needed for a permanent one-point fall in inflation—of approximately 2.7. This estimate is of the same order of magnitude as sacrifice ratios for other economies.

Section 4 studies the dynamic interactions among core inflation, headline inflation, and supply shocks. One finding is that movements in headline inflation appear to influence expected inflation and, hence, future levels of core inflation. As a result, a one-time supply shock, such as a large spike in food prices, can have a persistent effect on inflation. Like other aspects of India's inflation, this finding is reminiscent of inflation in advanced economies in the 1970s and 1980s.

Section 5 discusses some policy implications of our study. Although we have emphasized the usefulness of the weighted median inflation rate as a measure of core inflation, we, nonetheless, believe that conventional measures of headline inflation should still have a central role in monetary policy. One reason is communication with the public. Another reason is our finding that headline inflation feeds into expected inflation, and, hence, future core inflation. At the same time, it is vital for the RBI to examine core inflation to understand policy tradeoffs. We have used data on weighted median inflation to find a Phillips curve for India and estimate its slope, which we cannot do with headline inflation because of its quarterly volatility. Understanding the Phillips curve is essential for effective policies to control inflation.

2. There is a significant body of literature going back at least to Rangarajan (1983) and Dholakia (1990) that estimates the Phillips curve for India. Most of the early literature uses annual data and does not find much evidence for the existence of a short-run trade-off between inflation and output. See also Chatterji (1989), Rangarajan and Arif (1990), Das (2003), Virmani (2004), Bhattacharya and Lodh (1990), Balakrishnan (1991), Callen and Chang (1999), Nachane and Laxmi (2002), Brahmananda and Nagaraju (2002), and Srinivasan et al. (2006). However, more recently, several studies have used quarterly data and demonstrated the existence of a positive relationship between the output gap and inflation. Dua and Gaur (2009), Mazumder (2011), Patra and Kapur (2012), Kapur (2013), Kotia (2016), and Das (2014) are recent studies on the topic.

2. Core Inflation and Supply Shocks

Here we discuss the decomposition of headline inflation into core inflation and supply shocks, which is common in studies of inflation, and apply these concepts to quarterly data for India since 1994.

2.1. Background

By "core inflation," economists and central bankers mean an underlying trend in the inflation rate determined by inflation expectations and the level of economic activity, a trend that follows a relatively smooth path. The headline inflation rate is the sum of core inflation and "supply shocks," which reflect large changes in the prices of particular industries. Headline inflation is more volatile than core inflation.

The most common measure of supply shocks in empirical work is the change in the relative prices of food and energy. Consistent with this practice, core inflation is often measured by the inflation rate excluding the prices of food and energy. This practice is motivated by the fact that food and energy prices are volatile and that excluding them produces a much smoother inflation series.

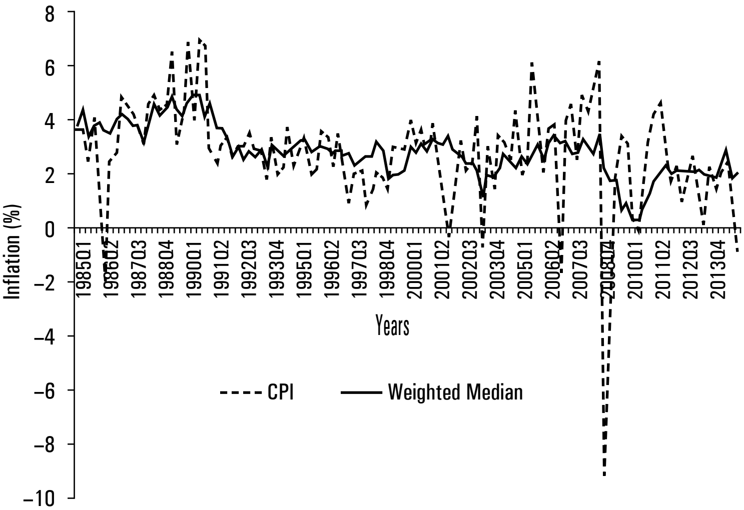
However, from a theoretical point of view, it is arbitrary to choose certain industries as the source of supply shocks and to exclude from the measures of core inflation. Ball and Mankiw (1995) define supply shocks as unusually large changes in the prices of *any* industries. They suggest that supply shocks be measured by the degree of asymmetry in the distribution of price changes across industries. If there is a tail of unusually large price increases, skewing the distribution to the right, that is, a supply shock that raises inflation, a tail of unusually large price decreases has the opposite effect. Ball and Mankiw motivate this view of supply shocks with models of costly price adjustment, in which large changes in firms' desired relative prices have disproportionately large effects on inflation, because they trigger price adjustment while other prices are sticky.[3]

3. Although the unusually large changes in the prices are assumed to be caused by "supply shocks" in Ball and Mankiw (1995), a tail of unusually large price increases, in our framework, has the same effect on the price change distribution and, hence, on inflation, regardless of whether it is determined by demand or supply factors. Gokarn (1997), for example, also examines the behavior of the skewness of the distribution of relative price changes in India over the period from 1982–1996 and interprets the skewness to be caused by supply shocks. See more below on this later.

If supply shocks reflect asymmetries in the distribution of price changes, then a measure of core inflation should strip away the effects of these asymmetries—it should eliminate the effects of the tails of the price distribution. A simple measure that does that is the weighted median of price changes across industries. This measure of core inflation is proposed by Bryan and Cecchetti (1994), and the Federal Reserve Bank of Cleveland maintains a measure of weighted median inflation for the United States.

Figure 1 (based on Ball and Mazumder 2014) illustrates these ideas for the United States by comparing headline CPI inflation to the weighted median of price changes across US industries for the period 1985–2014. We see that the weighted median filters out much of the quarter-to-quarter volatility in headline inflation, suggesting that it is a good measure of core inflation.

FIGURE 1. Headline CPI and Weighted Median Inflation: United States



Source: Authors' computation.

In US data, there is a strong correlation between median inflation and the common core measure of inflation excluding food and energy—but far from a perfect correlation. These findings reflect the fact that many of the large price increases filtered out by the median occur in the food and energy industries, but not all. Research on the United States finds that median inflation, with all large price changes removed, has less short-term volatility than inflation less food and energy.

In our following analysis, we find that in India, as in the United States, median inflation is substantially less volatile than headline inflation. Once again, the large price changes filtered out by the median occur largely but not entirely in food and energy industries.

We note that the traditional measure of core inflation, inflation less food and energy, is particularly unattractive for India. Given India's level of development, food is a large share of the aggregate economy, and its relative price has increased or decreased substantially for sustained periods. Thus, stripping out food prices leaves an inflation series that wanders far away from the headline inflation rate that is the ultimate concern of policymakers; it does not just dampen quarterly fluctuations in inflation.

2.2. Application to India

Here we begin to describe our empirical analysis for India. For some aspects of our approach, we outline what we do and provide details in the Appendix to the paper. The measures of inflation that we study are the rate of change in the headline WPI and core inflation in the WPI as measured by the weighted median inflation rate. We study the WPI because, starting in 1994, it has a relatively high level of disaggregation into industry inflation rates, which is critical for measuring median inflation. We note that the Central Statistical Organization (CSO) began releasing disaggregated CPI data in 2014. In future, these data could be used to compare headline and median inflation based on the CPI.

Historically, the WPI has been the most commonly used price index for measuring inflation in India.[4] Our raw data are monthly WPI prices disaggregated by industry from April 1994 through December 2014. We aggregate across three-month periods to create quarterly series from 1994Q2 through 2014Q4.

For each quarter, the headline inflation rate for the WPI is approximately the mean of inflation rates across industries, weighted by the importance of the industries.[5] We compare this inflation rate, as reported in official statistics, to the weighted median of inflation rates across industries—the inflation rate such that industries with 50 percent of the total weights have higher inflation rates and the others have lower rates. The set of industries

4. The term "wholesale" in the index is, however, misleading as the index does not necessarily measure prices in the wholesale market. In practice, the WPI in India measures prices at different stages of the value chain. As discussed in Srinivasan (2008), according to the National Statistical Commission, "in many cases, these prices correspond to farm-gate, factory-gate or mine-head prices; and in many other cases, they refer to prices at the level of primary markets, secondary markets or other wholesale or retail markets" (NSC 2001).

5. We computed the weighted mean of price changes across industries. As one would expect, this series closely follows the inflation rate calculated from the official series for the WPI.

and weights in the WPI are revised every decade, so our sample comprises one subsample from 1994Q3 through 2004Q1 with 61 industries and one from 2004Q2 through 2014Q4 with 81 industries. Given the discontinuity in the series, an approximation is needed to compute the inflation rate in 2004Q2, the first quarter with the revised set of industries (see Appendix for details). We use the second level of disaggregation that is available. Examples of industries include primary articles such as food (grains: cereals) and minerals (metallic) as well as manufacturing such as textiles (cotton: yarn) and electrical apparatus and appliances.

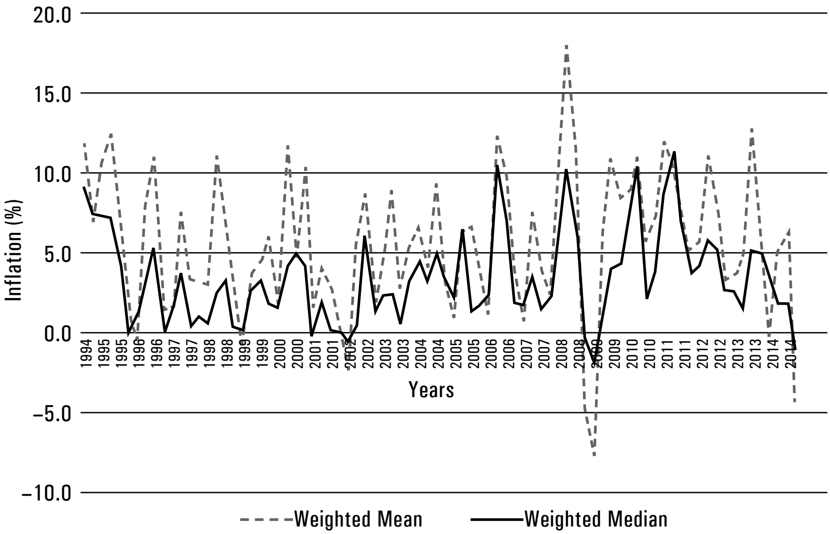
Figure 2 shows the series for official WPI inflation and weighted median inflation, with all quarterly inflation rates annualized by multiplying by 4. Panel A shows the series we construct from our raw data, which is not seasonally adjusted, and Panel B shows the series that are seasonally adjusted with the X-13 Arima-Seats procedure from the US Census Bureau. The seasonally adjusted and unadjusted series are highly correlated (correlation = 0.9 for median inflation), but the seasonally adjusted series are somewhat less volatile.

As expected, weighted median inflation is substantially less volatile than headline WPI inflation. For our seasonally adjusted series, the standard deviation of WPI inflation is 3.93 percent, while the standard deviation of the weighted median is 2.62 percent between 1994Q2 and 2014Q4.

We also find that the average level of median inflation over the sample, 3.43 percent, is substantially lower than the average level of WPI inflation, 5.56 percent. As we see in the figure, this result reflects the fact that WPI inflation often spikes up above median inflation, whereas median inflation is almost never substantially above WPI inflation (with only a few exceptions, for example, 2008Q4 and 2009Q1). This result is surprising, because in other economies, median inflation fluctuates fairly symmetrically around headline inflation and the average levels are similar, as shown for the United States in Figure 1.

Mechanically, WPI inflation exceeds median inflation when the distribution of industry price changes is skewed to the right—in other words, when there is a thick tail of large price increases. Figure 3 illustrates this fact with some examples of the cross-sectional distribution of industry price changes, based on the seasonally unadjusted series that we use initially to compute weighted medians. Panels A and B show the distribution of inflation rates for 2008Q2 and 2000Q2, two quarters in which WPI inflation is substantially greater than median inflation. In 2008Q2, industries including fruits and vegetables, fibers, other minerals, tea and coffee, and ferrous

FIGURE 2A. Quarterly WPI Inflation: Weighted Mean and Weighted Median



Source: Authors' computation.

FIGURE 2B. Quarterly WPI Inflation: Weighted Mean and Weighted Median (Seasonally Adjusted)

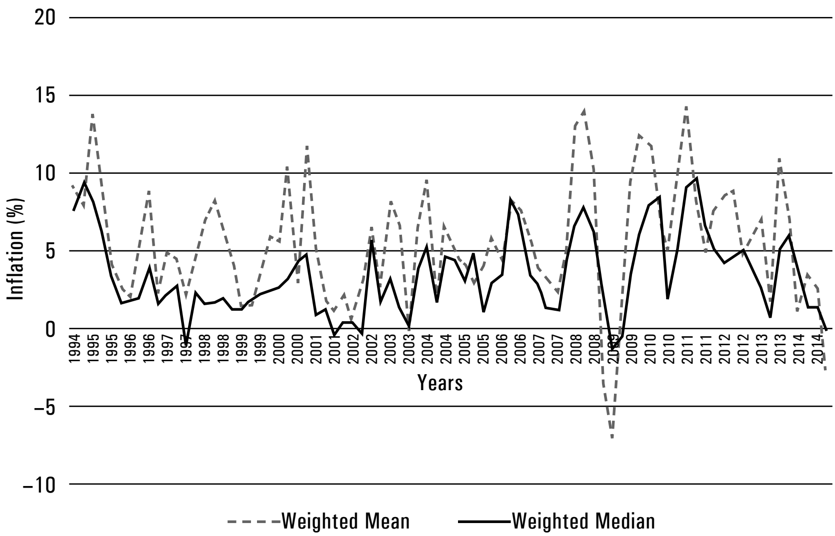


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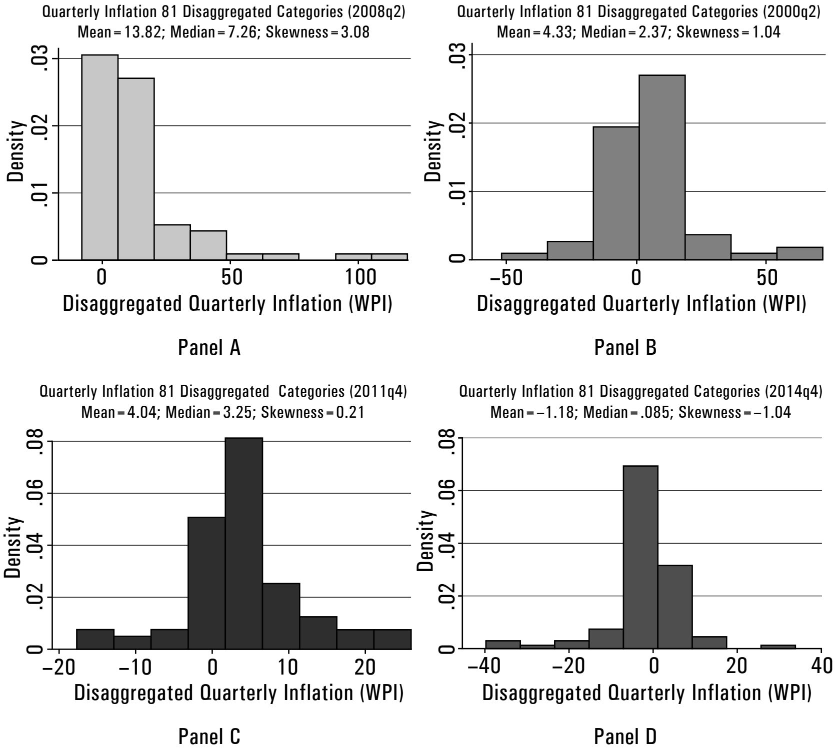
FIGURE 3. Cross Sectional Distribution of Industry Price Changes



Source: Authors' computation.

metals have inflation rates greater than 35 percent, and crude petroleum, metallic minerals, coal, food (others) have rates greater than 50 percent, creating strong skewness in the distribution. In 2000Q2, milk had a rate of 40 percent and rubber and mineral oils had rates greater than 60 percent. Panel C shows a sample quarter, 2011Q4, in which the distribution of price changes is close to symmetric, implying that WPI and median inflation are approximately the same. Panel D shows 2014Q4, a quarter with negative skewness. In 2014Q4, fruits and vegetables, other food, non-food fibers and oil seeds, crude petroleum, mineral oils, manufactured food: tea and coffee, bakery products, and oil cakes were in the left tail (lowest 10 percent) of the distribution and experienced inflation rates of –7.8 percent or lower.

2.3. The Role of Food and Fuel Prices

Changes in food and fuel prices cause many of the episodes of skewed price change distributions in India, as suggested by the example of 2008Q2. The same is true in advanced economies. To demonstrate this point systematically, we examine the industries that account for the top 10 percent of the weighted distribution of inflation rates in each quarter—the right tail of the distribution, which creates skewness in many quarters and raises WPI inflation above median inflation. Many of these industries are the producers of various kinds of food and fuel such as fruits, vegetables, milk, crude petroleum, coal, and electricity. For each of our industries, we examine its contribution to the right tail; of the distribution for each quarter. This contribution is zero if the industry is not in the 10 percent tail; the industry's WPI weight times 10 if it is in the tail; and it is somewhere in between if the industry's price change puts it at the border of the top 10 percent, in which case a part of the industry's weight is included in the tail. For each industry, we compute the average contribution to the 10 percent tail over our 82 quarterly observations on prices. These average contributions sum to 100 percent.

Recall there are 81 industries for the second part of our sample period; of these, 18 are different types of food (both primary articles and manufactured food) and four are different types of fuel or power. To see the influence of these industries more clearly, we aggregate them by one level into three broad industries: Primary Articles: food; Fuel & Power; and Manufacturing: Food. We also aggregate the other industries one level leaving us with 16 industries. For each of these industries, Table 1 shows the total of the average contributions of its components to the top 10 percent of price changes.

The results are striking. The three food and fuel industries are the three largest contributors to the 10 percent tail, with a contribution that sums to 63.5 percent. Notice if we add in non-food commodities, the fourth largest contributor, the total rises to 72 percent. Thus, if inflationary supply shocks are captured by right skewness in the price change distribution, Indian data confirm the common view that a large share of supply shocks originate in food and fuel industries—but not all. Notice that metals, chemicals, and textiles are also significant contributors to the 10 percent tail.

Figure 4 illustrates the importance of food and fuel in a different way. It shows two series: the difference between WPI inflation and median inflation, which captures the asymmetry in the distribution of price changes; and the change in the relative price of food and fuel, calculated as average inflation

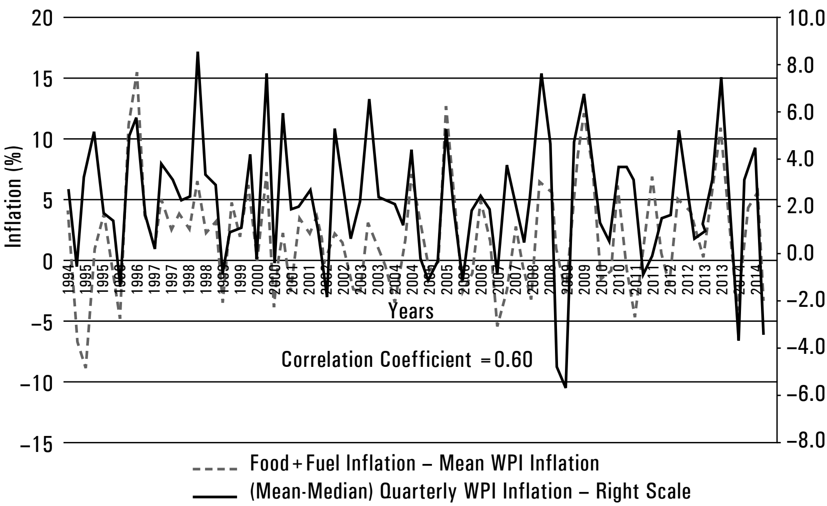
TABLE 1. Contributors to Top 10% of Price Changes

Industry	*Rescaled Weighted Frequency*
Primary Articles: Food	27.83
Fuel & Power	23.50
Mfg: Food	12.22
Primary Articles: Non-Food	8.50
Mfg: BM: Basic Metals, Alloys and Metal Products	7.55
Mfg: CC: Chemicals & Chemical Products	6.02
Mfg: Textiles	4.46
Primary Articles: Minerals	2.31
Mfg: NM: Non Metallic Mineral Products	1.95
Mfg: Paper & Paper Products	1.21
Mfg: MM:Machinery & Machine Tools	0.96
Mfg: BT: Beverages, Tobacco & Tobacco Products	0.95
Mfg: TE: Transport, Equipment & Parts	0.93
Mfg: Rubber & Plastic	0.85
Mfg: Leather & Leather Products (LL)	0.52
Mfg: Wood & Wood Products	0.25

Source: Authors' computation.

Notes. Weighted frequency is rescaled to sum to 100. Industries are sorted by weighted frequency. Total number of quarters = 82 (1994q3:2014q4)

FIGURE 4. (Mean-Median) WPI Inflation & Food + Fuel Inflation – WPI Inflation



Source: Authors' computation.

for food and fuel minus WPI inflation. We can see that the two series have a strong positive relationship. For the non-seasonally adjusted series shown here, the correlation is 0.60. The correlation is somewhat lower, 0.41, when we seasonally adjust both series. Once again, we see that increases in food and fuel prices explain a large share but not all of the right tails in the distribution of inflation rates.

3. A Phillips Curve for Core Inflation

The canonical Phillips curve explains inflation with expected inflation and the level of economic activity relative to the economy's potential. In many applications, researchers assume that expected inflation can be captured by lagged values of actual inflation. Here we examine the fit of a simple Phillips curve to core inflation in India, as measured by the weighted median.

3.1. Milton Friedman's Phillips Curve

A large body of research is based on the Phillips curve introduced in Milton Friedman's Presidential Address to the American Economic Association (AEA) in 1968. This relationship can be written as:

$$\pi_t = \pi_t^e + \alpha\,(x_t - x_t^*) + \epsilon_t \qquad (1)$$

where π_t is inflation, π_t^e is expected inflation, and x_t is a measure of economic activity, typically either the log level of output or the unemployment rate. The variable x_t^* is the long-run level of x, which is called the natural rate when it is unemployment and potential output when it is output. The term $x_t - x_t^*$ captures short-run fluctuations in output or unemployment. The error term ϵ_t captures unobservable factors that influence inflation.

This Phillips curve is exposited in leading textbooks in macroeconomics. The expected inflation term captures the idea that expectations of inflation tend to be self-fulfilling: if price and wage setters expect a certain level of inflation, they raise their nominal prices to keep up, and in aggregate their price increases create the inflation they expect. The $x_t - x_t^*$ term captures the idea that an increase in activity relative to the economy's normal level raises firms' marginal costs, which causes them to raise prices by more than they otherwise would.

Here we examine the fit of equation (1) to the behavior of core inflation. In Section 4 of this paper, we examine how core inflation and supply shocks interact to determine the behavior of headline WPI inflation in India.

To estimate equation (1), we must choose the measures of x_t, x_t^*, and π_t^e.

3.2. Measuring Economic Activity

We lack quarterly data on aggregate unemployment for India. Quarterly data on output, however, are available from the CSO. In our empirical analysis, we use quarterly GDP (at market prices) since 1996Q2. We combine the 2004–05 base-year GDP series and the 1999–2000 series to create a common series from 1996Q2 to 2014Q3, using a commonly used splicing methodology. The details of the splicing methodology are provided in Appendix 1. We measure activity x_t with the logarithm of output. Before taking the logarithm, we seasonally adjust the output series using the US Census Bureau's X-13 procedure. This adjustment is important because there are large seasonal movements in India's output.

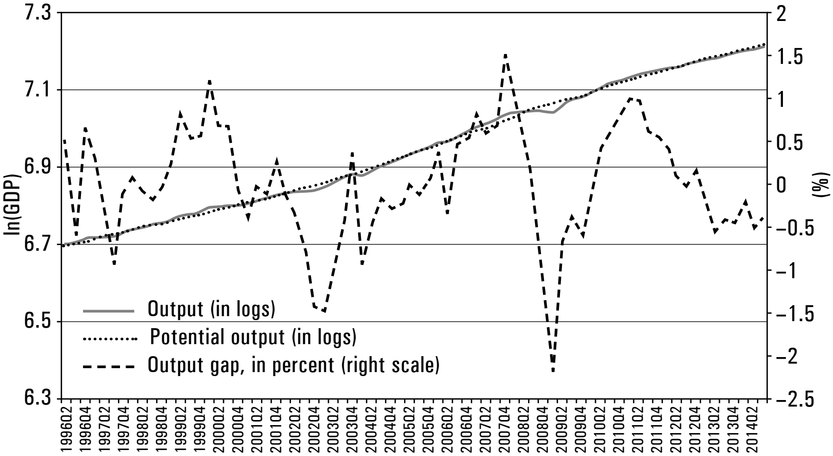
We measure potential output by smoothing the log output series with the Hodrick–Prescott (HP) filter, using a smoothing parameter of 1600. This common approach is atheoretical but yields a plausible series for x^*, and no other approach is obviously better in the absence of accurate, direct measures of the economy's productive capacity.[6]

Figure 5 shows the levels of x and x^* that we calculate, and the output gap $x - x^*$. The fluctuations in our measured output gap are consistent with common views about India's business cycle. The output gap was positive, with its magnitude being the highest during the sample, right before the 2008 global financial crisis (GFC). Output was recorded at 1.5 percent and 1 percent above its long-run potential in 2007Q4 and 2008Q1, respectively. Not surprisingly, the output gap was the most negative in our sample during the GFC. Output was 2.2 percent below its potential in 2009Q1. Our estimates also suggest a negative output gap of –0.4 percent for 2014Q3, or the last data point in our sample.

One questionable feature of the output gap series is that the size of fluctuations is small. The estimated output gap is never more than 1 or 2 percent in absolute value; even in the wake of the GFC, the gap reaches only –2 percent. By contrast, US output gaps as measured by the HP filter reach levels around 5 percent in absolute value in deep recessions and strong expansions. We are not confident that cyclical fluctuations in India

6. See Kotia (2016) and Mishra (2013) for the shortcomings of the HP filter.

FIGURE 5. Output, Trend, and Output Gap



Source: Authors' computation.

are as small as our estimated gaps suggest, and suspect that the quarterly data reported for real GDP could be smoother than true GDP. We will keep this issue in mind in interpreting our estimated effects of the output gap on inflation.[7]

3.3. Measuring Expected Inflation

In presenting his Phillips curve, Friedman said that "unanticipated inflation generally means a rising rate of inflation." This is the same as saying that expected inflation is determined by past inflation. Following Friedman, much of the US Phillips curve literature (for example, Ball and Mazumder 2011; Gordon 1982; Stock and Watson 2007) has used lags of inflation to capture expected inflation. With quarterly data, researchers typically include a number of inflation lags in the Phillips curve, with the restriction that the coefficients on the lags sum to one.

In recent years, inflation expectations have appeared to be "anchored" in advanced economies, including the United States and Europe. Since around 2000, the Federal Reserve and the European Central Bank have been targeting inflation rates near 2 percent, and expected inflation has stayed close to that level: expectations have *not* varied based on lagged values of actual

7. Some suggest using a lower HP smoothing parameter for emerging economies. This would produce even smaller estimated output gaps.

inflation. We doubt, however, that inflation expectations were anchored in India over our sample period. The RBI formally announced an inflation target only in 2015.[8] Over our sample, the inflation rate was volatile without a clear tendency to return to some fixed level, much as inflation rates wandered in the United States and Europe between 1960 and 2000. In such a regime, it is natural to assume that expected inflation responds to lagged values of actual inflation.

As we saw in Figure 2, quarterly core inflation is quite volatile in India—more volatile than core inflation in advanced economies. We conjecture that expected inflation is less volatile: A few quarters of high or low inflation do not change expectations dramatically. To capture this idea, we want to allow expected inflation to depend on lagged inflation over many quarters. At the same time, we do not want to include numerous lags with unrestricted coefficients; we want a parsimonious Phillips curve with a minimum of free parameters. These goals lead us to a simple partial adjustment model of expectations.

Specifically, we assume that expected inflation is determined by:

$$\pi_t^e = \gamma\pi_{t-1}^e + (1-\gamma)\pi_{t-1} \tag{2}$$

In this specification, expected inflation depends on its own lag and the lag of actual inflation with weights γ and $1-\gamma$. This implies that a one percentage point deviation of lagged inflation from its expected level changes current expected inflation by $1-\gamma$ percentage points. Repeated substitution for lagged inflation leads to the following reduced form:

$$\pi_t^e = (1-\gamma)\pi_{t-1} + \gamma(1-\gamma)\pi_{t-2} + \gamma^2(1-\gamma)\pi_{t-3} + \gamma^3(1-\gamma)\pi_{t-4} + \cdots \tag{3}$$

Here, expected inflation depends on all lags of past inflation, with exponentially declining weights. The adjustment parameter γ determines the relative weights on recent and less recent inflation rates. We treat γ as a parameter to be estimated.

If we write our equation for expected inflation compactly and substitute it into Friedman's Phillips curve (1), we get

$$\pi_t = (1-\gamma)[\Sigma_{k=1}^{\infty} \gamma^{k-1} \pi_{t-k}] + \alpha(x_t - x_t^*) + \in_t \tag{4}$$

8. See http://finmin.nic.in/reports/MPFAgreement28022015.pdf on agreement between the Government of India and RBI on the new monetary policy framework.

To estimate this equation with the available data, we must make two approximations, which we describe in Appendix 2. First, we truncate the infinite sum in the theoretical Phillips curve: We include only 40 lags of inflation with exponentially declining weights while maintaining the restriction that the weights sum to one.[9]

Second, we must address the problem that, even with the lags truncated at 40, we do not have data on median inflation that extends far enough back to include 40 lags in the early part of our sample. In our regressions, the sample starts in 1996Q2, the first quarter for which output data are available, and our median inflation series extends back only seven quarters before that, to 1994Q3. Since we cannot measure π_t^e for our entire sample, we treat π_t^e in 1996Q2 as an unobserved parameter, which we estimate along with the parameters γ and α in the Phillips curve. We estimate the initial π_t^e, γ, and α by non-linear least squares: We find the values of these three parameters that minimize the sum of squared residuals in the equation. Notice that an estimate of the initial π_t^e and an estimate of γ allow us to calculate π_t^e for all observations in our regression using the partial adjustment equation (3).

3.4. Estimates

Table 2 presents our estimation results. The estimate of the initial level of expected inflation is about 1.9, and the estimate of γ is 0.90, with a standard error of 0.05. If we put this estimate into our reduced-form equation for expected inflation, it implies that the first four inflation lags have coefficients of approximately 0.1, 0.09, 0.08, and 0.07, which sum to 0.34 out of the total sum of coefficients of one. This confirms that relatively long lags of inflation—beyond one year—have substantial weight in determining the current levels of expected and actual inflation in India, as we conjectured based on the volatility of quarterly inflation.

The estimate of the output gap coefficient α is 1.07 with a standard error of 0.54. The *t*-statistic of 1.99 puts the coefficient at the borderline of

9. Some readers of this paper have questioned the structure of inflation lags that we assume, so we have experimented with alternatives. As we expect, based on the volatility of inflation, a large number of lags is needed to capture the behavior of expectations. We verify this point by estimating a version of equation (4) in which we replace the exponentially weighted sum of inflation lags with 16 lags with unrestricted coefficients. In this specification, we reject the hypothesis that the coefficients on lags 13–16 are zero (p = 0.0383), which suggests that at least 16 lags are needed to fit the data. At the same time, when we include 16 unrestricted lags, the pattern of estimated coefficients on the lags is erratic, suggesting the model is over-parameterized. These findings confirm the usefulness of restricting the coefficients with our partial adjustment model.

TABLE 2. Phillips Curve Estimates

Dependent Variable	*Weighted Median WPI Inflation*
Output gap, α	1.074**
	[0.540]
Adjustment parameter, γ	0.902***
	[0.053]
Number pf observations	74
R-squared	0.19
Adjusted R-squared	0.179

Source: Authors' computation.

Notes: ***, **, and * denote statistical significance at 1,5, and 10 percent respectively. Standard errors are denoted in parentheses.

statistical significance at the 5 percent level. Thus, we find evidence of a substantial effect of output on inflation, the central prediction of the Phillips curve, but with considerable uncertainty about the magnitude of the effect.

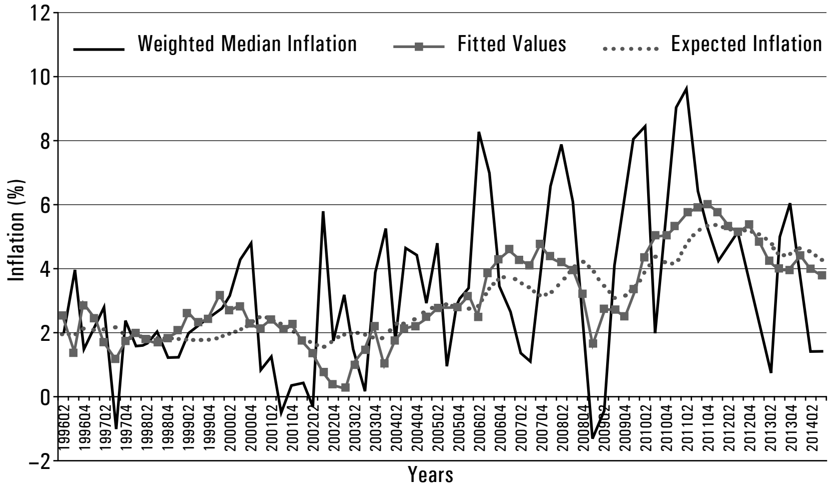
The top panel of Figure 6 shows our series for core inflation and the fitted values of this variable based on our estimated Phillips curve. This graph also shows the level of expected inflation implied by our estimate of the parameter γ; the deviation between this level and the fitted value of inflation is the estimated contribution of the output gap (the gap times the estimated value of α). The bottom panel of Figure 6 shows eight-quarter moving averages of the actual inflation, expected inflation, and fitted value series in the top panel. This graph smooths out much of the quarterly volatility in median inflation, allowing us to see how well our equation fits the somewhat longer-term movements in inflation.

With eight-quarter averages, the inflation movements over our sample are dominated by upward trends in actual and expected inflation from the early 2000s to 2012. Output movements help to explain some of the movements in inflation, such as the period around 2011–12 when the output gap was positive—as indicated by fitted values for inflation that exceed expected inflation—helping to push median inflation to its peak of around 7 percent. However, much of the long rise of inflation was generated by unexplained shocks to our Phillips curve, indicated by actual inflation above its fitted values. These shocks feed back into expected inflation in our partial adjustment equation, so a series of shocks pushed the level of inflation higher and higher. Negative shocks have partially reversed this process since 2012. We explore the nature of these shocks in Section 4 of this paper.

3.5. The Sacrifice Ratio

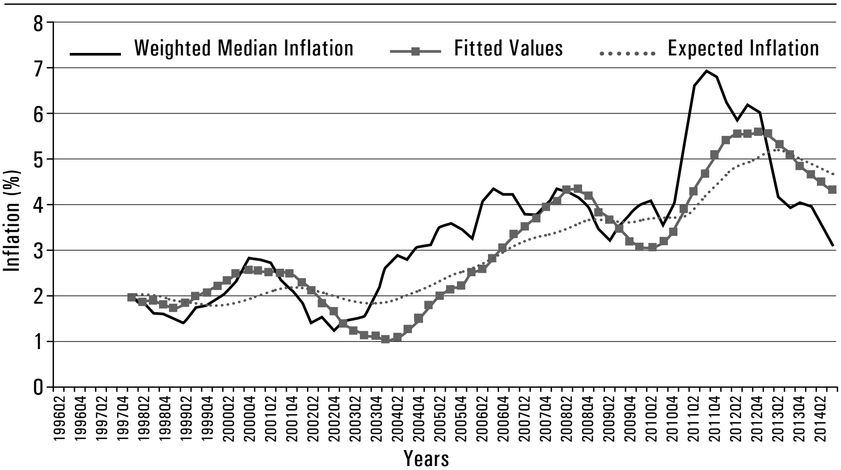
The RBI aims to reduce the inflation rate to 4 percent by 2018. The Phillips curve implies a cost to reducing inflation: absent a lucky disinflationary

FIGURE 6A. Phillips Curve Estimates with Weighted Median



Source: Authors' computation.

FIGURE 6B. Phillips Curve Estimates with Weighted Median: 8-quarter Moving Averages



Source: Authors' computation.

shock, policymakers need to reduce output temporarily below its trend to reduce inflation.

A common measure of the cost of disinflation is the "sacrifice ratio." This concept is the number of percentage points of reduction in annual output needed to reduce the inflation rate permanently by one percentage point. Estimates of sacrifice ratios in advanced economies in the 1980s and 1990s, before the recent period of anchored expectations, are often on the order of two or three. In other words, roughly a 2–3 percentage point loss of output relative to trend is needed to reduce the inflation rate in advanced economies by one percentage point (see Mitra et al. 2015, for a literature review).

Using our Phillips curve, we can calculate the sacrifice ratio as follows. A loss of output of one percentage point for one quarter reduces current inflation by α percentage points. Given our specification of expectations, that fall in inflation reduces expected inflation by $(\alpha) \times (1 - \gamma)$ in the following period. If output returns to normal at that point and there are no shocks to the Phillips curve, then actual inflation is $(\alpha) \times (1 - \gamma)$ below its initial level and stays there.

Thus, a one-point fall in output below normal for one quarter reduces inflation by $(\alpha) \times (1 - \gamma)$ points. A one-point fall in output that lasts for four quarters—a loss of one point of annual output—reduces inflation by $4 \times (\alpha) \times (1 - \gamma)$. The sacrifice ratio is the inverse of this effect: In order to reduce the inflation rate by one percentage point, a loss of $1/[4 \times (\alpha) \times (1 - \gamma)]$ percentage points of annual output is required.

Substituting in our estimates of γ and α yields a sacrifice ratio of 2.7, which is the same order of magnitude as estimates for other countries. If the current level of inflation is 5.2 percent and the RBI wishes to reduce it to 4 percent, the cost will be 1.2 × 2.7 = 3.2 percentage points of annual output. Notice that our estimated sacrifice ratio for India is quite close to estimates by Mitra et al. (2015) (around 2.3 or 2.8 depending on the state of the economy), despite large differences between their methodology and ours.

Two caveats: First, the RBI is targeting CPI inflation, whereas we calculate a sacrifice ratio for core WPI inflation. Future work should examine whether the relationships of output to CPI and WPI inflation are similar.

Second, as noted earlier, we suspect that quarterly output data may understate the size of short-run fluctuations. If so, the true output gaps associated with given changes in inflation may be larger than the estimated gaps, which would imply a larger sacrifice ratio.

4. Core Inflation, Supply Shocks, and Median Inflation

The previous section found that the behavior of India's core inflation, as measured by weighted median inflation, can be explained to a significant degree by a simple Phillips curve. We saw earlier, however, that many of the fluctuations in headline inflation are deviations from core inflation caused by supply shocks, as measured by asymmetries in the cross-sectional distribution of price changes.

Here we seek a broader understanding of India's inflation by examining the interactions among core inflation, headline inflation, and supply shocks. One finding is that movements in headline inflation appear to influence expected inflation and, hence, future levels of core inflation. As a result, a one-time supply shock, such as a large spike in food prices, can have a persistent effect on inflation. Like other aspects of India's inflation, this finding is reminiscent of inflation in advanced economies in the 1970s and 1980s.

4.1. A Phillips Curve for Headline Inflation?

As a first exercise, we examine how well the simple Phillips curve fits inflation behavior if we ignore the concept of core inflation and examine the headline WPI. In Table 3, the first column repeats our Phillips curve for median inflation, for purpose of comparison, and the second column reports

TABLE 3. Phillips Curve Estimates

Dependent Variable	*Weighted Median WPI Inflation* [1]	*Headline WPI Inflation* [2]	*Weighted Median WPI Inflation* [3]	*Weighted Median WPI Inflation* [4]
Output gap, α	1.074**	1.792*	1.063**	1.267
	[0.540]	[1.05]	[0.500]	[0.500]
Adjustment parameter, γ – Weighted Median	0.902***			
	[0.053]			
Adjustment parameter, γ – Headline WPI		1.022***	0.877***	
		[0.053]	[0.043]	
Adjustment parameter, γ – (constrained to be the same for Weighted Median WPI and Headline WPI)				1.086***
				[0.101]
Weight on average of past median inflation, β				0.256
				[0.277]
Number pf observations	74	74	74	74
R-squared	0.19	0.076	0.169	0.265
Adjusted R-squared	0.179	0.063	0.158	0.244

Source: Authors' computation.

Notes: ***, **, and * denote statistical significance at 1,5, and 10 percent, respectively. Standard errors are denoted in parentheses. β is the weight on an exponential average of past median inflation in the equation for determining expectations. The average of past headline WPI inflation rates has a weight of $1-\beta$. The exponential coefficient γ is constrained to be the same in the two averages.

estimates of an equation for headline inflation. This specification is the same as the first except that the dependent variable is headline WPI inflation and the lagged inflation rates with which we capture expected inflation are also WPI inflation.

It appears that this second Phillips curve is mis-specified. In particular, the estimate of the parameter γ is statistically indistinguishable from one (in fact, the point estimate is slightly above one). Our model of expected inflation, equation (3), assumes γ is less than one; as it approaches one, the adjustment of expectations diminishes to the point that expected inflation is constant. Thus, in this case, we fail to find any effect of past inflation on current inflation. Note also that the output coefficient α is less significant statistically ($p = 0.09$) than in our equation for median inflation. In sum, we fail to find strong evidence that headline WPI is explained by the variables on the right side of our Phillips curve.

This result, we believe, reflects the very great volatility of headline WPI inflation at the quarterly frequency. This noise in the series obscures any underlying Phillips curve. This negative result points to the desirability of examining median inflation when estimating the Phillips curve.

4.2. Core Inflation, Headline Inflation, and Expectations

Here we return to an equation with median inflation as the dependent variable. However, we consider the possibility that the lagged inflation terms on the right of the equation are headline WPI inflation. We interpret such a specification as saying that price setters base their expectations of inflation on past levels of headline inflation, so that movements in headline inflation are passed into future core inflation.

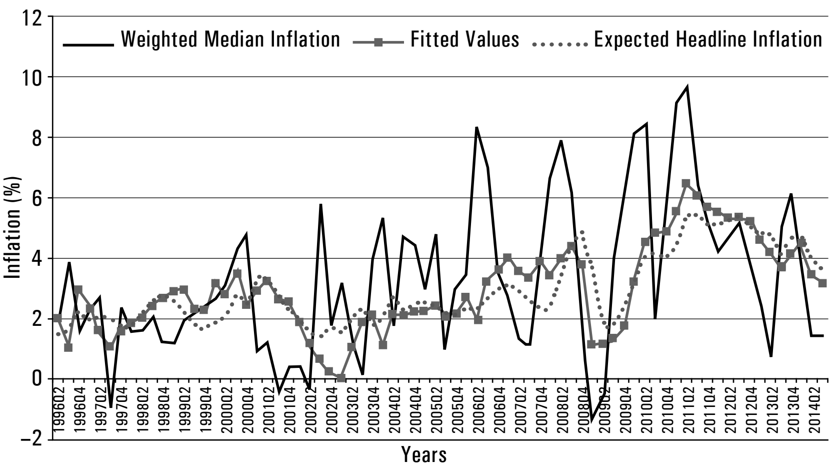
It is not clear *a priori* whether expected inflation should depend on the past levels of headline inflation or core inflation. Empirically, a number of studies for the United States find a sharp break in inflation behavior around the Volcker disinflation of the early 1980s. Inflation is explained by lags of headline inflation before that time and by lags of core inflation afterwards. The usual interpretation is that price setters in the 1970s based their expectations on past headline inflation, so expected inflation responded to movements in headline inflation even if those movements were the result of transitory supply shocks. After the Volcker disinflation, however, it became clear that the Federal Reserve was determined to reverse transitory inflation movements due to supply shocks, so those shocks no longer influenced expectations and actual inflation going forward. In the terminology of central bankers, in the post-Volcker era, supply shocks have first round effects—they directly affect current headline inflation—but not second round effects on expectations and future inflation.

Before using lagged headline inflation rates to explain median inflation, we account for the fact that headline inflation is systematically higher than median inflation—the difference averages 2.42 percentage points over the sample period for our regressions. We subtract this constant from the headline WPI series, resulting in an adjusted series with the same average value as the median. We can interpret this specification as explaining median inflation with lagged levels of headline inflation, both measured relative to their sample averages.

The third column of Table 3 reports this specification. The results for this case are quite close to those with median inflation on both sides of the equation, in column [1]: the estimates of α and γ are similar, and so are the *R*-squared. The estimate of γ is well below one in both economic and statistical terms, unlike the case with WPI inflation on the left. Comparing columns [1] and [3], it appears that we can explain median inflation about equally well when we measure expected inflation with the lags of median inflation and headline inflation.

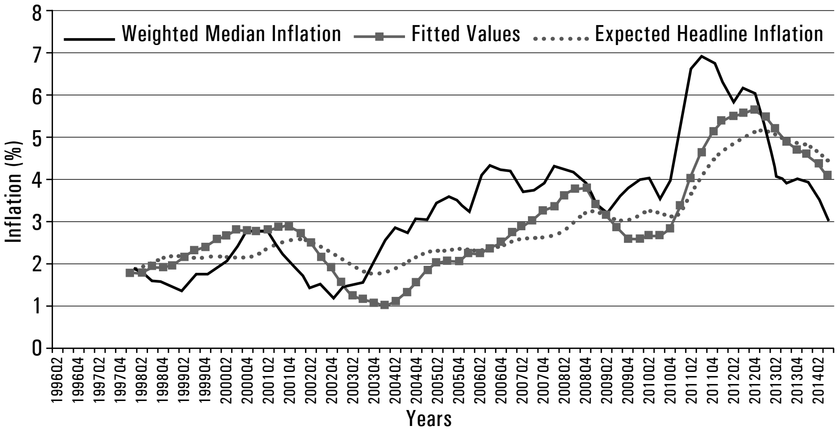
For the regression with median inflation on the left and lagged headline inflation on the right, Figures 7A and 7B show actual median inflation, expected inflation, and fitted values from the regression, along with eight-quarter moving averages of these series.

FIGURE 7A. Phillips Curve Estimates with Weighted Median and Headline Inflation Expectations



Source: Authors' computation.

FIGURE 7B. Phillips Curve Estimates with Weighted Median and Headline Inflation Expectations: 8-quarter Moving Averages



Source: Authors' computation.

In column [4] of Table 3, we investigate whether lagged headline or lagged core inflation belongs on the right side of the Phillips curve equation by including both in a horserace.

Here, we assume that an exponential average of past median inflation has a weight of β in determining expectations, and an average of past WPIs has a weight of $1 - \beta$. Notice that we constrain the exponential coefficient γ to be the same in the two averages; the qualitative results are similar if we estimate two different γs.

Our estimates for this specification are imprecise. This reflects the fact that median inflation and WPI inflation have similar medium-term movements; thus, while these two inflation rates have only a modest correlation at the quarterly frequency, the slow-moving averages of the two are strongly correlated, so there is a problem of multicollinearity.

Nonetheless, we can see where the estimates point. The key result is that the estimate of the weight β on past median inflation is 0.26 with a standard error of 0.28. A two-standard error confidence interval is [–0.30, 0.82]. While this range is wide, we can reject the hypothesis that β is one—that only past median inflation affects expectations—and cannot reject the hypothesis that is zero—that only past headline inflation matters. The estimate of γ exceeds one, but this may simply reflect sampling error, as a two-standard error band extends down to 0.88.

In sum, the data suggest that past headline inflation has a substantial effect on expected inflation, so, as in the pre-Volcker United States, a supply shock that raises inflation in one quarter can have a persistent effect on core inflation through its effect on expectations.

4.3. Food and Energy Again

Throughout our analysis, we have examined the effects of changes in the relative price of food and energy, measured by food and energy inflation minus aggregate WPI inflation. This relative price changes when there are events in the real economy affecting the supply and demand for food and energy. In our framework, large shocks of this nature influence aggregate inflation; again, the underlying theory is that of Ball and Mankiw (1995), in which large shocks have disproportionately large effects on inflation because they trigger the adjustment of nominal prices that might otherwise be sticky.

In India, economists debate the reasons for rises and falls in food prices. In particular, some cite supply-side factors such as low and stagnant production of food and others emphasize demand factors such as shifting diets. We do not take a position in this debate, and our results do not shed light on it. In our framework, a large shock to food and fuel prices has the same effect on the price change distribution and, hence, on inflation, regardless of its underlying demand or supply causes.

Much of the literature on India's inflation investigates the interactions of food inflation—the change in the nominal price of food—with non-food inflation or aggregate inflation. In our view, such empirical analyses do not have a clear interpretation. A change in food prices is an event in the real economy only to the extent it differs from aggregate inflation; otherwise, it is simply part of the inflationary process affecting all prices.

In an accounting sense, one can explain aggregate inflation with an equation that includes different components of inflation. If all the components are included, one obtains an equation with an *R*-square of one and coefficients on each component equal to its share in the aggregate price index. Even if only one or a few components are included in the equation, they can appear to have high explanatory power if movements in aggregate inflation cause correlated movements in the inflation rates for many industries.

A similar point applies to studies that regress aggregate inflation or non-food inflation on lags of food inflation or other sectoral inflation rates. In these equations, lagged food inflation may simply be a proxy for lagged aggregate inflation if there is a strong common component in the inflation rates of different sectors. Whether a measure of food inflation is contemporaneous or lagged, it can tell us something about the determinants of inflation only if it is measured relative to aggregate inflation.

In Table 4, we include the change in the relative price of food and energy, measured by food and energy inflation minus headline inflation, in the estimation of the Phillips curve. The dependent variables are weighted median and headline inflation in columns [1] and [2], respectively. Not surprisingly, as shown in column [1], the relative price of food and energy does not have a significant effect on weighted median inflation, which is stripped of volatile components. Column [2] shows that the relative price of food and energy *does* have a statistically significant effect on headline inflation. The estimated coefficient is 0.43 and the standard error is 0.14. The results support the earlier evidence that changes in the relative price of food and energy, which predominantly constitute the right tail of the distribution of price changes, strongly influence aggregate inflation.

TABLE 4. Phillips Curve Estimates with Relative Price of Food and Energy

Dependent Variable	*Weighted Median WPI Inflation*	*Headline WPI Inflation*
	[1]	*[2]*
Output gap, α	1.062**	1.918*
	[0.523]	[1.148]
Adjustment parameter, γ – Headline WPI	0.866***	1.004***
	[0.044]	[0.062]
Food and Energy Inflation – Headline WPI Inflation	0.056	0.429***
	[0.108]	[0.139]
Number pf observations	74	74
R-squared	0.1725	0.1726
Adjusted R-squared	0.1492	0.1493

Source: Authors' computation.

Notes: ***, **, and * denote statistical significance at 1,5, and 10 percent, respectively.

5. Some Policy Implications

Our findings have implications for the roles of different measures of inflation in monetary policy and for the tradeoffs facing policymakers.

We have emphasized the usefulness of the weighted median inflation rate as a measure of core inflation. Nonetheless, we believe that conventional measures of headline inflation should still have a central role in monetary policy. One reason is communication with the public. Headline inflation is a meaningful variable for non-economists, whereas the concept of median inflation and its usefulness are technical issues that would be difficult to explain. When central banks around the world discuss the inflation rate and set targets for its level, they generally refer to headline inflation, and there is no reason for India to deviate from this practice.

Even if we ignore communication issues, there is a strong case for the RBI to base policy on the headline inflation rate; for example, to tighten policy when a supply shock pushes headline inflation above median inflation. The reason is our finding that headline inflation feeds into expected inflation and, hence, future core inflation. This state of affairs contrasts with many advanced economies today, in which expectations appear not to respond to supply shocks. In those economies, policymakers can largely ignore movements in headline inflation and focus on stabilizing core inflation.

Yet, the behavior of expectations is not set in stone. In the future, a commitment by the RBI to offset the inflationary effects of supply shocks could cause inflation expectations to behave more like expectations in advanced economies. If that happens, then Indian policymakers can focus on stabilizing core inflation and pay less attention to supply shocks.

Even under current circumstances, it is vital for the RBI to examine core inflation to understand policy tradeoffs. We have used data on weighted median inflation to find a Phillips curve for India and estimate its slope, which we cannot do with headline inflation because of its quarterly volatility. Understanding the Phillips curve is essential for effective policies to control inflation.

Our finding of a Phillips curve tradeoff is both good news and bad news for policymakers. The good news is that the central bank can push inflation to a desired level by stimulating or dampening aggregate demand, regardless of supply side developments. The bad news is that lowering the level of inflation requires a sacrifice, which we estimate to be 2.7 percentage points of annual output per percentage-point reduction in inflation.

Our finding of significant costs of disinflation is consistent with the international experience. In both advanced and emerging economies, a policy of reducing inflation almost always reduces output in the short run. This is true even when disinflation is accompanied by the supply-side reforms aimed at increasing long-term growth and even when policymakers announce a clear and credible inflation target (see, for example, Bernanke et al. 1999).

6. Conclusion

Leading macroeconomics textbooks explain inflation with a Phillips curve in which the inflation rate depends on expected inflation, the level of output relative to trend, and supply shocks. Typically, the models assume that expected inflation is determined by lags of the inflation rate and that supply shocks are largely changes in the relative prices of food and energy. One-time supply shocks can have persistent effects because they feed into expectations. In this framework, a central bank can guide inflation to a desired level, but if inflation starts above this level, it is costly to reduce it, and it can also be costly to offset supply shocks and prevent them from raising inflation.

While still common in textbooks, this model of inflation is considered to be somewhat less relevant now for advanced economies including the United States and Europe. In these economies, in the 2000s, a commitment to an inflation target has led to an anchoring of inflation expectations, which makes it easier for central banks to maintain stable inflation with less cost to output stability. In contrast, we have seen that the textbook model explains much of the behavior of inflation in India in recent years. Time will tell whether inflation behavior will change under the RBI's new monetary framework.

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APPENDIX

Appendix 1. Data Details

Median Inflation in 2004Q2

There is a discontinuity in the monthly series on industry price levels that we use to calculate weighted median inflation. A new series begins for each industry in April 2004, and it is not comparable to the earlier data. In addition, 20 industries are added, bringing the total number from 61 to 81. For our quarterly analysis, this break in the data makes it difficult to measure median inflation for 2004Q2.

We approximate median inflation in 2004Q2 as follows. We use the 61 industries that exist both before and after the quarter. For each industry, we assume that the gross monthly inflation rate for April 2004 is the geometric average of the gross inflation rates for February, March, May, and June 2004. With this industry inflation rate in hand, we can compute a consistent series of monthly price levels that spans April 2004. We aggregate monthly price levels to get quarterly price levels for each industry, calculate quarterly inflation rates, and then calculate weighted median inflation for the 61 industries.

Splicing Methodology for GDP Series

We compute a consistent series for real GDP (before seasonal adjustment) using two series with base years of 1999–2000 and 2004–05. Essentially, we project the 2004–05 series (which starts in 2004Q2) backwards using the growth rates from the 1999–2000 series. Specifically:

For observations starting in 2004Q2, we use the output levels from the 2004–05 base year series.

We work backward to get output in 2004Q1, 2003Q4, and so on, using the formula

$$y_t = \frac{y_{t+4}}{(1+g_{t+4})}$$

where y_t and y_{t+4} are output levels in quarters t and $t + 4$, and g_{t+4} is the growth rate of output from t to $t + 4$. For all the observations for 2004Q1 and earlier, g_{t+4} is computed from the output series for base year 1999–2000. For observations from 2004Q1 back to 2003Q2, y_{t+4} is from the output series with 2004–05 base year. For observations for 2003Q1 and earlier, y_{t+4} comes from an earlier step in our backward iteration.

Appendix 2. Details of Estimation

To estimate the Phillips curve, equation (4), we make two approximations to our equation for expected inflation, equation (3).

First, we truncate the series of inflation lags after 40 quarters, adjusting the coefficients so they still sum to one. This yields

$$\pi_t^e = \frac{(1-\gamma)}{(1-\gamma^{40})}\left[\sum_{k=1}^{40}\gamma^{k-1}\pi_{t-k}\right] + \in_i$$

Second, we must address the problem that data on 40 lags of median inflation are not available for the early part of our sample. We assume that the level of expected inflation in 1996Q3, the first observation in our regression, is some unobserved level π_0^e. This is observationally equivalent to assuming that actual inflation is constant at π_0^e in all quarters before 1996Q3. We estimate this parameter along with the parameters gamma and alpha in the Phillips curve by non-linear least squares.

Comments and Discussion*

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The paper by Ball et al. investigates the behavior of quarterly inflation in India since 1994, including headline as well as core inflation. The paper examines the distinction between headline and core inflation. Core inflation denotes the underlying trend in inflation, while headline inflation fluctuates around the core inflation due to supply shocks. Often, core inflation is measured as the inflation rate excluding the price of food and energy. Since food and energy prices are the volatile components of inflation, core inflation is considered to be less volatile than headline inflation. The authors measure core inflation by the weighted median of price changes across industries based on the approach developed by the Federal Reserve Bank of Cleveland. They find that the weighted median is less volatile at quarterly frequency than headline inflation. To implement this approach, they examine the inflation rate calculated from the wholesale price index (WPI).

First, the authors suggest that supply shocks reflect asymmetries in the distribution of price changes and that core inflation, measured by the weighted median of price changes across industries, should eliminate the effects of these asymmetries. The authors note that a measure of inflation that excludes food prices is not appropriate for the Indian economy, since food is an important component of the consumption basket. The reason mentioned by the authors for using WPI is the high level of disaggregation into industry inflation rates since 1994, which is critical for measuring median inflation. The paper uses quarterly data from Q2 April 1994 to Q4 December 2014.

Second, the paper reports the estimation of a Phillips curve for core inflation. Core inflation at quarterly frequency is modeled to depend on expected inflation, which is determined by past levels of inflation and by the level of economic activity as captured by the deviation of output from its long-run trend. The main findings of this estimation suggest the following:

* To preserve the sense of the discussions at the IPF, these discussants' comments reflect the views expressed at the IPF and do not take into account revisions to the original conference paper in response to these and other comments, even though the IPF Volume itself contains the revised paper. The original conference version of the paper is available on www.ncaer.org.

1. Current core inflation depends upon several lags of past inflation with weights that decline slowly. This finding reflects slow adjustment of expected inflation.
2. There is a positive relation between inflation and deviation of output from trend. Along with the finding regarding the slow adjustment of expectations, this implies that monetary policy can reduce inflation, but with a short-run cost in the form of a decline in output.
3. This is further shown by estimating the sacrifice ratio to be 2.7, which is of the same order of magnitude as the estimates for other countries. This implies that if the current level of inflation is 5.2 percent and the RBI wishes to reduce it to 4 percent, then the cost will be $1.2 \times 2.7 = 3.24$ percentage points of the annual output.

Third, the authors study dynamic interactions among core inflation, headline inflation, and supply shocks. One of their findings is that movements in headline inflation appear to influence expected inflation, and hence future levels of core inflation. As a result, a one-time supply shock, such as a large spike in food prices, can have a persistent effect on inflation. They also find that supply shocks in terms of food price changes feed into expectations and have an effect on aggregate inflation.

My comments on the paper are as follows:

1. The reason why the authors use the WPI index to measure core as well as headline inflation in India is quite clear. Core inflation is measured as a weighted median of prices across industries using WPI disaggregated data. The authors have added a caveat in the paper that since consumer price index- (CPI) disaggregated data is available after 2014, it can be used for future analysis. Some of the advantages of CPI are noted here for future research.

   The Government of India (2010; 2011) document provides the new CPI index from 2011 onwards while also giving the rationale for the shift in emphasis from WPI to CPI. A study by Patnaik et al. (2011) asserts that CPI should take center stage for policy purposes among all existing inflation measures in India. The CPI reflects the consumption bundle of households and is, thus, more relevant than any other measure of inflation. Second, the CPI for Industrial Workers (CPI-IW) also reflects the prices of food as accurately as the other measures. Third, CPI-IW includes the prices of services, which are not included in any other measure of inflation. Furthermore, the WPI or the Producer Price Index (PPI) largely reflects global prices of tradeables expressed in rupees. The monetary policy of the RBI has a minimal role in influencing these, other than through the exchange rate. The CPI, on the other hand, has a large share of non-tradeables. Monetary policy has a much bigger role to play in influencing the prices of domestic non-tradeables. Thus, macroeconomic analysis and policy thinking in India may steer toward CPI and away from WPI. Basu (2011), in a Finance Ministry document, cites the advantages of using CPI inflation in policy making. Gupta and Siddiqui (2014) also note the benefits of using CPI over WPI for policy purposes.

2. The authors measure core inflation as a weighted median of price changes across industries. However, other methods are available to measure core inflation. These include the exclusion method, limited influence method, trimmed mean, weighted mean, common trends method, and smoothing techniques. Studies such as Durai and Ramachandran (2007), Goyal and Pujari (2005), Dua and Gaur (2010), and Raj and Mishra (2011) provide various measures of core inflation in India. These alternative measures may also be considered.
3. For measuring expected inflation, the paper uses the partial adjustment model of expectations, which makes use of lags of inflation. The paper includes 40 lags of inflation with exponentially declining weights while maintaining the restriction that the weights sum to one. However, this lag structure is very high and a smaller lag structure may be sufficient to capture the effect of past inflation. The long lag structure may also lead to the problem of multicollinearity.
4. The authors do not give a rationale for using backward-looking expectations. The question that arises is whether this analysis will also hold for the Phillips curve with forward-looking expectations. Inflation expectations can be measured in different ways. Dua and Gaur (2010) employ four estimation specifications for forward-looking expectations, that is, naïve forecast, perfect foresight, Autoregressive Integrated Moving Average (ARIMA) model (one quarter ahead and four quarter ahead forecast), and a measure of core inflation. An IMF study by Patra and Ray (2010) also uses the ARIMA approach to measure inflationary expectations in India.
5. There is a broad comparison between the Phillips curve for core inflation and headline inflation where the results presented suggest that the Phillips curve with the WPI headline inflation as the dependent variable seems to be misspecified. When expectations are measured in terms of core inflation, the adjustment parameter is below 1, otherwise it is estimated as above 1. Similarly, the coefficient (α) for the output

gap has a value above 1. These magnitudes seem to be perverse, possibly due to the omitted variable bias in the model. Furthermore, does this imply that the authors are trying to suggest that for policy purposes in future, the central bank should target core inflation rather than headline inflation?

6. In the abstract, the authors mention that large changes in relative prices arise mainly, but not exclusively, in industries that produce food and energy. However, this point is not shown explicitly by using the econometric model.
7. The Phillips curve should be estimated in a multivariate framework. Dua and Gaur (2010) use an extensive list of variables in their paper to estimate the Phillips curve for certain countries including Japan, Hong Kong, Korea, Singapore, the Philippines, Thailand, Mainland China, and India. These factors can be further divided into demand and supply factors. The demand factors include both domestic factors (for example, output gap, real money gap) and external factors (for example, exchange rate, import inflation). The supply factors also include both domestic factors (for example, food inflation, rainfall, the differential between wage inflation and productivity) and external factors (for example, global oil prices).
8. Finally, the results of the paper may be compared with the findings for other emerging market economies that have been discussed in Dua and Gaur (2010), among others.

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Let me begin by saying that this paper is a welcome contribution to the discussion of inflation in India and to the India Policy Forum. It provides a clear and concise presentation of the contemporary analysis of inflation dynamics for India. In particular, the authors apply a well-known and statistically straightforward method for defining core inflation and estimating the sources of short-run inflation volatility used for the USA and other advanced economies to the study of inflation in India. I appreciate the opportunity to discuss a paper by three experts, Laurence Ball, Anusha Chari, and Prachi Mishra, on inflation dynamics, based on extensive research by Ball and others on inflation in other countries.

The authors begin the paper with the measurement of core inflation. Since inflation in the short run is much more volatile than in trend, we need a measure of inflation that distinguishes transitory fluctuations from persistent movements in the price level to understand inflation dynamics. Definitions of core inflation are attempts to remove high frequency fluctuations in nominal prices from the underlying persistent components of inflation. A possibly useful way to think about core inflation is that the difference between core and headline inflation is motivated by the classical dichotomy between the monetary and real sides of the economy, that is, trend inflation ought to be due to monetary phenomenon only, as suggested by Milton Friedman in his presidential address to the American Economic Association in 1968. In the presence of nominal rigidities, short-run changes in the price level, however, can arise from either non-monetary or monetary disturbances. Short-run inflation volatility can be caused by monetary policy, and transitory shocks can lead to persistent changes to inflation through monetary policy responses. The last three words of my previous sentence are essential. Several recent commentaries on inflation in India have asserted that food price shocks cause persistent inflation. Without monetary accommodation, this is not a sensible assertion.

In this paper, core inflation is measured by a weighted median of price changes in the disaggregated WPI data. This reduces the impact of volatile and skewed price changes for individual product categories on overall inflation. Other limited influence estimators could also be used to remove the transitory effects due to price changes in the tails of skewed distributions. In their original paper, Bryan and Cecchetti (1995) proposed and compared trimmed means and dynamic factor indices in addition to weighted medians as candidates for limited influence estimators of core inflation. If nominal rigidities find their source in menu costs, then unexpected price changes are made by firms that experience the largest idiosyncratic shocks because the seller's desired price change must exceed its menu cost (as in Ball and Mankiw 1995). Such threshold effects generate differences between mean and median inflation that tend to be transitory. Limited influence estimators and alternative econometric-based estimators, for example, Quah and Vahey (1995), should be preferred to ad hoc definitions of core inflation for studying inflation dynamics, particularly the sources of inflation persistence. Ad hoc definitions such as the US version of core inflation based on all items less food and energy identify cost shocks with price volatility in particular industries rather than with shocks per se. This might be useful for transparent communication of monetary policy, but only when it provides a good approximation to a statistically based definition.

Ball, Chari, and Mishra illustrate the difference between the weighted median and weighted mean inflation in their Figure 2 and show that food and fuel contribute significantly to price changes in the upper tail of the distribution. As emphasized in the presentation, mean inflation is persistently higher than median inflation in the WPI for India, and the average weighted mean significantly exceeds the average weighted median of inflation for the sample period. This tells us that the distribution of price changes is right-skewed, and price changes in the upper tail are not symmetrically offset by lower tail changes. This is confirmed by the cross-sectional distributions of price changes illustrated in Figure 3. The distribution of price changes for advanced economies (shown for the USA in the paper) is more symmetric and does not display a pronounced difference between median and mean inflation. One concern is that the weighted mean and median measures differ on an average because price changes in the upper tail include permanent increases in the nominal prices of particular goods. This can be consistent with idiosyncratic, infrequent adjustment of nominal prices, given large menu costs. With large menu costs, the mean would always exceed the median in a steady state with constant positive inflation. However, fluctuations in the difference between the mean and median could reflect transitory inflation.

In this case, weighted median inflation may not be a very appealing measure of core inflation for guiding monetary policy. A natural, alternative approach would be to estimate permanent and transitory components of inflation, following Stock and Watson (2007). Although an econometric method does not have the transparency of a fixed, readily replicated statistic for communicating monetary policy decisions, the persistent shortfall of weighted median inflation from the trend rise in the price level for India may severely limit its usefulness in this regard. I would appreciate seeing a comparison of trend inflation from an unobserved components analysis to limited influence estimators for India included in the paper. Incidentally, the use of limited influence estimators has been suggested before for India (for example, by Mohanty, Rath, and Ramaiah 2000).

The second part of the paper uses the weighted median inflation rate to estimate the contribution of real activity to inflation using the Friedman–Phelps accelerationist Phillips curve. Expected inflation is backward-looking and represented by a moving average of lagged inflation. The implicit model of price setting behind the econometric equation suggests that producer price inflation (PPI), and not consumer price inflation (CPI), should be used. Inflation in the WPI is an imperfect substitute, but unfortunately, a proper PPI is not available for India. The estimated Phillips curves are fairly interesting; one thing I learned from the results is that these work for Indian data. Ball, Chari, and Mishra find evidence that changes in real economic activity as measured by deviations of GDP from HP-filtered trend GDP have a significant influence on current inflation.

The estimations of the Phillips curve include expected inflation and the output gap. Weighted median inflation is the dependent variable in regressions 1 and 3 of Table 3. Equation 3 uses headline inflation to estimate backward-looking inflation expectations. The model behind this specification is Ball and Mankiw (1995), in which mean inflation is regressed on lagged inflation rates and skewness of nominal price changes (the interaction between skewness and standard deviation of the cross-sectional distribution of price changes). Replacing headline inflation (weighted mean inflation) by a limited influence estimator of core inflation eliminates the need for the skewness term. Reporting regression 2, in which the dependent variable is headline inflation, reinforces the conclusion that headline inflation responds to transitory price shocks drawn from an asymmetric distribution. Regression 1 uses weighted median inflation to represent inflation expectations, thus removing fluctuations in the difference between weighted mean and median inflation from the right-hand side. Supply shocks enter the preferred regression (3) through the expectations variable. Table 4 shows the results of including food and energy inflation as a separate regressor. I think this is especially useful because it shows that food and energy prices do not influence core inflation any differently than do other sources of average inflation. Although the results do suggest that the authors' choice of a limited influence estimator is superior to headline inflation for estimating the Phillips curve, I would appreciate seeing a comparison with the alternative measure of core inflation estimated from an unobserved components model.

An alternative to the backward-looking Phillips curve is the New Keynesian Phillips curve (NKPC). Expected inflation is forward-looking in an NKPC, and the equation itself is derived from an optimizing model of price setting. In an IMF working paper, Anand, Ding, and Tulin (2014) present a new Keynesian general equilibrium model for the Indian economy that includes forward-looking expectations in the aggregate supply curve. A critique of the NKPC is that it does not perform as well empirically as the backward-looking Phillips curves, even for advanced economies. Including a discussion comparing backward-looking and forward-looking expectations would be helpful for placing the empirical model used here into the contemporary theory of aggregate supply and price dynamics. I think that this is also important for interpreting what the Phillips curve tells us about monetary policy in India. Essentially, what I glean from the estimation in Ball, Chari, and Mishra is that the output gap significantly affects inflation in India. The slope of the Phillips curve may help explain the success of the recent, post-2013, disinflation.

My first critique returns to the measurement of core inflation. The argument in favor of adopting a simple statistical measure of core inflation relies on the credibility of a transparent and easily replicated inflation statistic to communicate the objectives of monetary policy. Credibility is not likely to be gained if core inflation fails to track actual trend inflation well. Simplicity can be appealing (as seen by the US choice of definition) but not at the sacrifice of usefulness. The systematic discrepancy between weighted median inflation and headline inflation probably will not help make this a good core inflation estimator for either guiding or communicating monetary policy decisions. Both the Bank of Canada and the Federal Reserve Bank of Cleveland publish econometrically derived estimates of trend inflation.

Such estimated core inflation measures may serve better for understanding the dynamics of inflation and the efficacy of monetary policy for meeting price-level stabilization goals. At present, India probably needs better guides for monetary policy and better measures for studying the inflationary process (and inflation persistence, in particular) more than it needs an alternative to headline inflation for the central bank to communicate with the public. I suggest using the already mentioned approach of Stock and Watson to identify trend inflation for India.

The second critique is to ask whether we learn very much that is important for monetary policy in India from estimating a Phillips curve. The title of the paper, "Understanding Inflation in India," suggests that we might learn something about the persistence of inflation in India, the contribution of monetary policy to reducing or propagating inflation, and the formation of inflationary expectations in India. The paper does provide some insight into the importance of extreme price changes in particular product categories. In combination, primary food and manufactured food products comprise 40 percent of the upper tail cross-sectional price changes. The volatility of food prices drives future inflation through lagged headline inflation in the regression analysis. The predominance of food prices in outliers in individual product inflation distributions should not lead us to conclude that there is something special about food inflation, but rather about how large positive changes in individual producer prices drive inflation.

Inflation persistence has been a concern for monetary policymaking and analysis, and it has been a subject of other recent contributions to the India Policy Forum. The authors find persistence coming through the backward-looking component in the regression equations. The estimate for the geometric weight on lagged inflation, gamma, is about 0.9. The literal interpretation is that adaptive expectations adjust slowly. Another interpretation is that monetary policy accommodates aggregate supply shocks and that inflation expectations take account of this. Decomposing inflation into transitory and permanent components could help us to understand the formation of inflation expectations and how cost shocks contribute to inflation. Cogley, Primiceri, and Sargent (2010) propose that the dynamics of the gap between inflation and trend inflation measures the effectiveness of monetary policy for achieving the long-run inflation targets of monetary policymakers. I think that looking more deeply into the inflation process in India econometrically would yield greater understanding of inflation in India. The Reserve Bank of India has adopted a flexible inflation-targeting framework. We will learn if inflation expectations become better anchored in time, as we learn whether inflation in India can be tamed. A statistical analysis to elucidate our understanding and to enable monetary authorities to choose policy responses to inflationary and deflationary shocks should probably be based on econometric tools rather than on statistical simplicity.

I found this paper to be interesting and informative. It is a useful contribution to the IPF. In conclusion, I found the comparison of the recent inflation experience of India to inflation in the USA in the 1970s and 1980s very insightful and provocative. The authors point out their observation that the debates over inflation in India sound a lot like the same debates in the USA in the 1970s and 1980s. I very much look forward to more research on the inflation and monetary policy in India and further progress in taming inflation.

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General Discussion

Rajnish Mehra asked the authors what use their inflation data should be put to. For example, temperature data designed to assess global warming would have to be filtered very differently if we were assessing temperature changes in Delhi next week. Similarly, the paper's inflation data would have to be understood differently if it were to assess, say, short-term monetary policy vs identifying structural reforms.

Nirvikar Singh agreed with Pami Dua that the paper's 40-period-distributed lag estimation seemed like too much inertia in the adaptive equation for expected inflation. He recommended six to eight lags, which would then not need restrictions on the coefficients of the geometrically declining wages and also provide an easy robustness check. Fewer lags may mean estimating more coefficients but would mean perhaps not having to deal with missing-not-at-random data, which would make robustness checks easier and more practical.

Vijay Joshi, agreeing with Ken Kletzer, argued that to understand the trajectory of inflation in India, an important thing to consider must be the policy reaction function, which the paper seemed to lack in an explicit way. The several years of high inflation in India post the global financial crisis could possibly be attributed to the Reserve Bank of India (RBI) following an overly accommodative monetary policy. But, it would not be possible to say anything about this hypothesis using the paper, since it lacks a policy reaction function.

Joshi felt that the paper did not help understand what goes into inflationary expectations in India. The paper notes that inflationary expectations depend on supply shocks but does not go into the how or why of such a dependency. Indexation such as used for dearness allowance or Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) wages could be a shock, but so could the announcement of the Minimum Support Price (MSP) for the government's agricultural procurement. If policy makers had a better feel for this, and research could provide the clear underlying evidence, we might then have better policies. We might, for example, do something about the MSP to deal with inflationary expectations.

Karthik Muralidharan commented on how the monetary side of inflation played into the real economy and had a question about the lowest level of aggregation at which this analysis of inflation would make sense for a continental sized economy like India's. How, for example, might the paper's most striking result about the difference between core and headline inflation vary by the level of aggregation that we adopt? This led to his second point about whether it is the lack of market integration in domestic food markets that accounts for the huge variation between the median and mean and the gap between core and headline. Should not the paper reference the considerable work done on food markets and the barriers, whether physical or policy induced, that may be preventing the emergence of an efficient national food market? Getting rid of these barriers may perhaps do more for inflation in the first instance than anything monetary policy could do.

Ila Patnaik highlighted two questions going back to the morning keynote address by Rajiv Mehrishi, India's Finance Secretary, when he mentioned the monetary policy framework agreement (MPFA) signed by the RBI and the Union Government in February 2015. First, the MPFA says that the objective of monetary policy should be price stability, with RBI targeting an inflation rate of 6 percent (±2 percent) in 2016 and 4 percent (±2 percent) beyond that, using CPI inflation as proposed by the Urjit Patel Committee. Can the findings of the paper inform the policy discussion about which measure to use, since it is likely that MPFA will get enshrined soon in an RBI Act Amendment bill? And given the analysis of volatility in the paper, what should the band be, since the ±2 percent has been put in arbitrarily? Second, Patnaik noted that if her understanding was correct, the paper showed that expectations responded more to headline than core inflation, and, if so, how should optimal monetary policy react to shocks in food and fuel prices? Overall, she felt that the paper should focus more on the policy implications of its findings.

Surjit Bhalla noted, first, that RBI should construct CPI series for both urban and rural areas and then generate a composite CPI series, going back several decades: RBI has been collecting CPI data for the last 65 years, and this should not be difficult to do since Prachi was at RBI. Second, Bhalla suggested that inflation in India can be seen in three phases: 1960 to 1996, when it averaged about 8.5 percent; 1996 to 2004–05, when it averaged about 4.3 percent; and 2006 to 2013, when it averaged above 10 percent. He felt that any policy research on inflation should answer the question of why high inflation persisted for some 35 years, then remained very low for a decade, and then rose significantly again for some six years. At a minimum, he felt that such research should be able to "reject" the following explanations for persistence, at least since the 1980s, that inflation had persisted because of: (a) globalization and the effects of global inflation on India and (b) the high, relative price of food, which he felt is not determined by droughts, but by the MSP. Once we admit that these explanations are inadequate, we can make real progress. Third, Bhalla was delighted that the paper had estimated a core inflation rate of 5 percent but wondered how this would be received at RBI, given its own expectations survey that is consistently showing inflationary expectations of 10–11 percent inflation. Finally, Bhalla noted that annual data show nothing more than two-year lags, so using 10-year lags was really a problem and could just be noise in the authors' calculations. Why not just use the annual data?

Dilip Mookherjee, professing his non-macro credentials, said that he was a little mystified why items like food and fuel should be excluded in calculating inflation. The rejection of outliers could be understood if there were significant measurement errors, but that was not the case here. While endorsing Kletzer's argument that the authors should filter out the effects of transitory supply shocks, he suggested that they could confine themselves to mean inflation and get some measure of trend inflation, even as they filter out the transitory shocks. He also suggested that there was an identification problem with respect to the lags, pointing to several other reasons for the lags, such as inventories, durables, collusion, and price fixing. He urged the authors to make stronger efforts to ascertain the cause of the lagged effects.

Anusha Chary and Prachi Mishra thanked the participants for their comments, responded to the key issues raised, and said that they would seek to incorporate them into the revised paper.

Bimal Jalan (Chair) concluded the discussion by reiterating the need for using some measure other than just CPI, even though there is a greater all-round backing for using CPI over WPI. He also suggested that the paper's discussion of the significant relationship between output and inflation would help not only in understanding inflation but also tackling inflation using policies and mechanisms that would cause the least real impact.