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DYNAMICS OF INFLATION "HERDING"

DECODING INDIA'S INFLATIONARY PROCESS

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ABSTRACT

Compared to immediately preceding years, that is, its own recent history, India's inflation became unhinged (thereby reversing creditable performance) from as far back as 2006. The paper puts forward an empirical framework to analyze the time series and cross-sectional dynamics of inflation in India using a large panel of disaggregated sector prices for the time period, 1994/95 to 2010/11. This allows us to rigorously explore issues that have been, at best, loosely posed in policy debates such as diffusion or comovement of inflation across sectors, role of common and idiosyncratic factors in explaining variation, persistence, importance of food and energy price changes to the overall inflation process, and contrast the recent experience with the past. We find, *inter alia*, that the current period of high inflation is more cross-sectionally diffused, and driven by increasingly persistent common factors in non-food and non-energy sectors compared to that in the 1990s; this is likely to make it more difficult for anti-inflationary policy to gain traction this time round compared to the past. The paper has also introduced a novel measure of inflation, viz., Pure Inflation Gauges (PIGs) in the Indian context by decomposing price movements into those on account of: (1) aggregate shocks that have equiproportional effects on all sector prices; (2) aggregated relative price effects; and (3) sector-specific and idiosyncratic shocks. If PIGs, in conjunction with our other findings, for example, on persistence had been used as a measure of underlying (pure) inflationary pressures, the monetary authorities may not have been sanguine regarding the timeliness of initiating anti-inflationary policies.

INTRODUCTION

From a broad scanning of the Indian economy, it is not difficult to misinterpret Indian economic managers' attitude towards inflation, for the most part, as cynical. Consumer price inflation (CPI) has been virtually in double digits for three years and the wholesale price index (WPI) has accelerated and stayed stubbornly high.[1] Compared to immediately preceding years, that is, its own recent history, India's inflation became unhinged, thereby reversing creditable performance, from as far back as 2006. In the last two years, among its major comparators India has the highest rate of consumer inflation; it is also volatile in relation to its peers in Asia and the BRICs[2] (see Table 1). It would seem that India has decoupled when it comes to price behavior; therefore assertions that imported inflation and external developments—like global excess liquidity—lies at the root of price developments in India ring hollow.

The paper has been motivated in no small part to official pronouncements seemingly unencumbered by methodological rigor. There are several grounds for distrust by citizens regarding policy makers in this context. Firstly, officials have attributed the upswing in prices (measured by all indices) to food supply constraints, and therefore claim they are powerless to do anything about it. Secondly, they resort to hand wringing and public communication that essentially amounts to "we are staring the problem down" as the common refrain for an inordinately long time; in tandem, rolling "(mental) spreadsheet forecasts"—that have been optimistic by some distance—were, and still are, put out at regular intervals to give succor and hope to the public. Thirdly, a spate of recent statements seems to suggest that the medium-term objective of around three percent inflation articulated by *inter alia* the Reserve Bank of India (RBI)[3] is being given a quite burial.

Disquieting and, frankly, obvious questions need to be raised on public policy grounds. A senior (and serious) official earlier this year described six percent annual inflation as "comfortable", and "quiet acceptable"—comfortable and acceptable to whom? Is the suspension of long-standing sound, conservative, inflationary targets temporary, or, is this the new "normal"? Answers to these questions aside, what is clear is that persistence of elevated inflation is agreeable to some policy makers. The authorities want to take credit for India's growth performance but stay blameless on the price front—a case of heads I win, tails you lose! (see Table 2). Is there a reluctance to admit that the Indian economy has crossed its "speed limit", but growth is being prioritized over price stability? Answers have been scarce.

While high inflation is being purveyed by some as necessary, or an inevitable synchronicity for the strong growth performance, it would seem that other important stakeholders also tasked with navigating and managing aggregate demand are being driven astray on inflation:

> "Our inflation emanates from the supply side more often. If you look at the inflation basket with CPIs and WPI, food has 46 to70 percent in the CPI basket. If on 46 to 70 percent of the basket I have not much influence, how can I deliver on inflation target? Which inflation target do we target? We have one wholesale price index and four consumer price indices. For a country with 1.2 billion people, fragmented markets and vast heterogeneity, can we have a single number representing Nagaland, Kerala and Orissa at the same time?" (Subbarao [2010]).

This is an astonishing series of nihilistic statements—unassisted by evidence or even a hint of scientific thoroughness—from the central bank head pleading

Table 1: Annual Percentage Change in Consumer Prices

	Average 1993 - 2002	2003	2004	2005	2006	2007	2008	2009	2010	Proj. 2011
All advanced economies	2.2	1.8	2.0	2.3	2.4	2.2	3.4	0.1	1.6	2.2
Major advanced economies	1.9	1.7	2.0	2.3	2.4	2.2	3.2	-0.1	1.4	2.0
Newly industrialised Asian economies	3.1	1.5	2.4	2.2	1.6	2.2	4.5	1.3	2.3	3.8
Developing Asia	6.8	2.7	4.1	3.8	4.2	5.4	7.4	3.1	6.0	6.0
Latin America	39.3	10.4	6.6	6.3	5.3	5.4	7.9	6.0	6.0	6.7
Major emerging economies:										
India	7.2	3.8	3.8	4.2	6.2	6.4	8.3	10.9	13.2	7.5
China	6.2	1.2	3.9	1.8	1.5	4.8	5.9	-0.7	3.3	5.0
Brazil	103.5	14.8	6.6	6.9	4.2	3.6	5.7	4.9	5.0	6.3
Russia	95.3	13.7	10.9	12.7	9.7	9.0	14.1	11.7	6.9	9.3
South Africa	7.6	5.8	1.4	3.4	4.7	7.1	11.5	7.1	4.3	4.9
Indonesia	13.8	6.8	6.1	10.5	13.1	6.0	9.8	4.8	5.1	7.1
Turkey	72.0	25.3	8.6	8.2	9.6	8.8	10.4	6.3	8.6	5.7

Source: IMF [2011].

either hopelessness on account of India being a large and diverse Federal entity, or, a form of muddled eclecticism. Let us deconstruct the statement. First, recent inflation dynamics are being wholly attributed to narrow sectoral drivers. *Prima facie*, in combination with the evolution in core inflation (a measure excluding food and petroleum components) it may be construed as seeking to absolve the monetary authority from pursuing low and stable inflation as even a primary—let alone an overriding or dominant—objective in the hierarchy of macroeconomic goals. Second, it is impossible to know which price index to target presently, and presumably in the future, since India will continue to be geographically diverse and culturally heterogeneous! Hence, it is not possible to pursue a useful or credible inflation objective on which the central bank can be assessed. Third, a consensus among policy makers, both in government and the central bank, and acceptance by market participants that stability of inflation, as measured by the WPI, will be pursued seems to have been cast aside and degraded in terms of priority. In other words, an important "focal point" has been virtually dropped from the central bank's price stability lexicon if this speech is anything to go by.

This is in stark contrast to the awareness (sensitivity) shown by then Finance Minister's statements in Parliament on the subject of inflation in the early 1990s:

Table 2: Fiscal-Financial-Monetary Indicators, 1994/95 to 2010/11

	Overall fiscal deficit (% of GDP)	Seignorage (% of GDP)	M3 growth (%)	Interest on central govt. dated securities (%)	Headline (WPI inflation) (%)	Gdp growth rate (%)
1994/95	9.7	3.0	19.8	11.90	12.6	6.4
1995/96	8.3	2.1	15.6	13.75	8.0	7.3
1996/97	8.4	0.4	16.2	13.69	4.6	8.0
1997/98	9.4	1.7	17.0	12.01	4.4	4.3
1998/99	11.4	1.9	19.8	11.86	5.9	6.7
1999/00	11.2	1.1	17.2	11.77	3.3	6.4
2000/01	10.6	1.1	15.9	10.95	7.2	4.4
2001/02	11.0	1.5	16.0	9.44	3.6	5.8
2002/03	9.8	1.3	16.1	7.34	3.4	3.8
2003/04	9.8	2.4	13.0	5.71	5.5	8.5
2004/05	8.3	1.6	14.0	6.11	6.5	7.5
2005/06	7.9	2.2	15.4	7.34	4.4	9.5
2006/07	6.1	3.2	20.5	7.89	5.4	9.6
2007/08	4.9	4.4	22.1	8.12	4.8	9.3
2008/09	10.5	1.1	20.5	7.69	8.3	6.8
2009/10	11.0	2.6	19.1	7.23	3.8	8.0
2010/11	9.5	2.8	16.0	NA	8.9	8.6

- "The people of India have to face double digit inflation, which hurts most the poorer sections of our society. Inflation hurts everybody, more so the poorer segments of our population whose incomes are not indexed." (Government of India (GoI) [1991]).
- "The Government will remain fully vigilant on the prices front and will use the Public Distribution System to counter inflation and in particular to protect the poorer sections of the population from high prices and shortages." (GoI [1992]).
- "Inflationary expectations have not yet been purged from the system and inflationary pressure could easily build up again if fiscal discipline is relaxed." (GoI [1993]).

Obviously there is no confusion about inflation metrics and motivation for price stability as a national policy goal by India's most admired Finance Minister. Therefore, taken together, the above enunciations raise the obvious question of whether political or pol-

ity preferences have changed regarding tolerable and acceptable levels of inflation.

It could be that policymakers have not been remiss in "wait and watch," founded on diagnosing the recent bout of inflation as narrowly based, that is, catalyzed by specific sectoral causes and shocks which will reverse themselves. *Ipso facto*, headline inflation will decline, in some ways, of its own accord (sans timely activist policy). Was the expectation that inflation in specific sectors would stay contained and not transmit or diffuse through into other sectors? The converse has transpired which has pushed up core sector inflation and engendered expectations of higher generalized inflation. Assertions apart, convincing evidence has not been forthcoming. It was hoped that drivers of the extant spell of inflation were unlikely to continue, which does not appear to be based on any known analysis.

Alternatively, it may be argued that policymakers deliberately chose to "fall behind the curve" in formulating, communicating and implementing requisite/optimal decisions. Were errors of judgment made in accommodating individual price level shocks, or, impulses emanating from the supply side? Furthermore, did the government's loose fiscal-financial-monetary stance evident in recent years impart pressure to keep government borrowing rates low or negative in real terms (see Table 2)?[4] In this context, pursuit of quantitative easing (seignorage) would be an important factor, otherwise why pursue this course of action after a self imposed hiatus, and against the spirit—if not the word—of the September 1994 agreement between the central bank and the Ministry of Finance.[5]

There is an established tradition for studying inflation in India. Much of this entails modeling macroeconomic interactions between output, prices and money, deploying variants around a vector autoregression framework using quarterly data (Bhattacharya and Kathuria [1995], Roy and Darbha [2000], and Patra and Ray [2010], among others). The work has often been against the background of a lively debate between two schools of thought, viz., Monetarism and Structuralism, where differences are primarily due to variation in the underlying output-price determination mechanisms emanating from differences in perceived structural characteristics of the economy (Balakrishnan [1991]).[6]

While we don't comment on—let alone delve into—the merits or demerits of the WPI, our choice price series is informed by the following:[7]

- Inflation measured by the WPI is used by the RBI to keep track of price developments. In addition, over the past two decades, indications in official documents regarding comfort bands/zones, projections, estimates etc. have been in terms of this index.
- In terms of disaggregation (that is, number of commodities) it is the most comprehensive among indices available.
- Most importantly, the paper puts forward a formal scaffolding to understand inflation dynamics irrespective of price data series. If the RBI uses the WPI to inform its conduct of monetary policy—which it does—then, we feel, it should bring to bear on the WPI the operational framework that we put forward.

The paper attempts to comprehensively probe changing aspects of India's inflation dynamics informed, guided and disciplined by deploying diverse estimation techniques and specifications, some of which are atypical. While we are motivated by recent developments in aggregate inflation we use disaggregated price data, thereby preserving the statistical power of a large panel data set. Although there is a lot of

discussion on sector prices and its relationship with aggregate developments, comprehensive analysis that pools information in large dimensional panels available for India are conspicuous by their absence. (Mishra and Roy [2011] is a recent exception but their focus is on accounting for importance of food price inflation.) After all, depending on viewpoints and context, investigation of both aggregate and disaggregated multi-sector price outcomes should be informative for macroeconomists. For instance, it is useful to rigorously gauge how broad based sector inflation is for a given overall headline measure. While policy makers have tools to influence overall inflation, the magnitude of the challenge is, in no small part, determined by the extent to which inflationary impulses (dynamics) have played out, or permeated, within and across sectors on account of standard input-output price transmissions. The more broad based inflation is—especially when converging to a high headline rate, say—the more stubborn it is likely to be, that is, less amenable to amelioration with minimal output losses. This perspective is at the heart of taming generalized inflationary expectations, especially in the context that India finds itself in at present: high inflation in comparison to its own recent past and in relation to its peers.

Overall, we allow the inflation data *per se* to "do the talking". Against the background of long standing conceptual work in macroeconomics, finance-theoretic approaches to empirically investigate "convergence/herding" in price movements and debates within the country, the paper applies eclectic methodologies to investigate the behavior of and the interrelationships between aggregate inflation and disaggregated core sectoral inflation over time (the latter is obtained after stripping away direct and indirect impacts of food and energy price movements). The emphasis on dynamics is informed by: (i) the unexceptionable observation that the Indian economy is undergoing large changes since the 1990s; and (ii) public comments by decision makers seem to convey that policy objectives are changing, or at least being re-examined, in recent times.

The plan for the rest of the paper is as follows. In section two, we briefly review some relevant conceptual work on inflation that forms a backdrop to our empirical investigations in subsequent sections. It is natural that we begin by investigating the time-series evolution of cross-sectional density functions of sector price changes, a so-called *moments approach* (Section Three). In light of the positive and increasing skewness observed in recent years, we examine the possibility of rising comovement among sector inflation rates by analyzing (i) "response coefficients" of sector inflation to movements in aggregate inflation; and (ii) the number and the amount of variation explained by common dynamic factors (section four).[8] Following on, in the same section we estimate the persistence of common factors vis-à-vis sector specific factors for establishing whether or not incessant sector influences are holding sway in adversely impacting broader (headline) measures of inflation, say, through an input cost and/or wage-good price spiral, rather than broad macro influences, say, demand management and expectations driven. In section five, we put forward a novel measure of inflation, Pure Inflation Gauges (PIGs), in the Indian context. The dynamic common factor estimation exercise introduced in the previous section allows us to decompose sector price movements into those on account of (i) aggregate shocks that are common and have equiproportional effects; (ii) aggregated relative price effects; and (iii) idiosyncratic sector specific factors (Reis and Watson [2010]). Section six concludes the paper, followed by all tables and figures.

MOTIVATION FOR INVESTIGATION

The empirical approach we follow in subsequent sections has been broadly influenced by the large literature on how rigidities at the industry level result in connections between aggregate inflation and shifts in relative prices. Supply shocks are intrinsically changes in certain relative prices, but it is not, *prima facie*, clear why such relative price changes drive mean economy-wide aggregate inflation. Friedman has persuasively argued that relative price changes cannot be overall inflationary without accommodation from requisite monetary policy. But the high correlation between components of money growth and inflation associated with the quantity theory assumes that nominal prices are perfectly flexible. For supply shocks to drive aggregate inflation in the absence of monetary accommodation, micro-level frictions/nominal rigidities, delays, and misperceptions in disparate markets are needed (Ball and Mankiw [1992b]). An implication is that higher order moments—variability and skewness—in inflation data become important, more so in a univariate but eclectic multidimensional analysis that is adopted in this paper (see, among others, Fischer [1981], Hercowitz [1981], Mills [1927] and Vining and Elwertowski [1976]).

An important source identified in this context has been an asymmetry driven by costs pertaining to price adjustments. Firms are more likely to alter their prices in response to large shocks rather than small ones because of menu costs; in other words, there is a range of inaction.[9] It follows that since firms react to large shocks more quickly than to small shocks, the desired increases occur more swiftly than the desired decreases and the price level rises in the short run; consequently, changes in the price level are positively related to the skewness of relative price changes across sectors and industries. If the distribution of desired changes in relative prices is skewed to the right then shocks will engender *average* price level rises in the short run.

Alternately, if there are systemically important sectors, like food and energy, characterized by flexible, responsive prices, while other sectors are typified by sticky or relatively rigid prices, then exogenous supply and weather shocks quickly drive increases in the relative price of the fast adapting sectors, which can raise the aggregate price level.

Supply shocks are intrinsically changes in certain relative prices, but it is not clear why such relative price changes drive mean economy-wide aggregate inflation.

Some other models show that trend inflation and adjustment costs lead to asymmetries because with positive trend inflation a lower desired relative price comes about passively, while a positive aggregate shock drives a wedge between the actual relative price, which declines, and the desired one, which incentivizes an upward price revision even in the presence of an adjustment cost. Therefore, upward adjustments in prices are larger than downward ones, and inflation rises in periods of high relative price variability; with positive inflation, relative prices are adjusted upward more quickly than they are adjusted downward (Ball and Mankiw [1992a]). Overall price stability eliminates this asymmetry.

In the presence of menu costs and monopolistic firms that produce a non-storable product whose demand depends on its price relative to the price level of commodities (considered as an aggregate) a higher rate of perfectly anticipated inflation leads to a larger nominal price adjustment in each period (Sheshinski and

Weiss [1977]). A natural corollary is that expectation of higher trend inflation is likely to accentuate skewness of the cross-sectional distribution and increased comovement of sector inflation rates in this general class of forward looking models.

To investigate whether such patterns are corroborated by the data, we analyze, in what follows, the time series evolution of cross-sectional densities of sector inflation rates and determine whether there is a perceptible change in the cross-sectional moments in recent times.

RESULTS: MOMENTS APPROACH

To give an initial sense of cross-sectional patterns, for the years 1994/95 to 2010/11, we investigate the time series evolution of Kernel Density Function (KDF) plots of the following:[10] [11]

i. Annual inflation for 54 groups, across 360 individual commodities, comprising the core sectors (non-food, non-energy) of the wholesale price index (core sector-WPI), $\pi^{c}_{i_t}$.[12]

ii. Residuals from the following regression for core commodity groups:

$$\pi^{c}_{i_t} = \alpha_i + \sum_{i=0}^{I} \phi_{t-i} \text{ food inflation}_{t-i} + \sum_{i=0}^{I} \gamma_{t-i} \text{ energy inflation}_{t-i} + \varepsilon^{c}_{i_t} \quad (1)$$

where I = 0, 1, 2, ...

iii. Annual inflation for 63 groups, across 520 individual commodities, comprising the entire WPI (WPI-all), π_{i_t}.

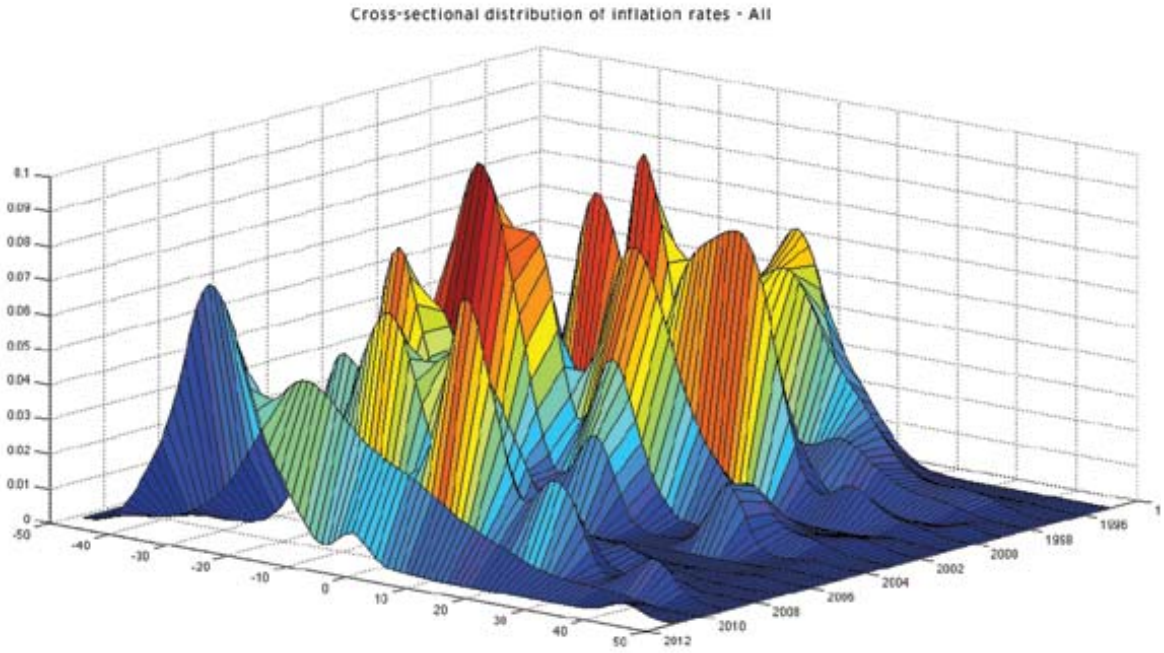
Much of our analysis is concentrated on variables (i) and (ii). For the latter, the motivation is to expunge, as far as possible, effects of food and energy on core components of the WPI; that is, eliminate higher order effects of food and energy emanating from input-output considerations and supply shocks leading to wage-price linkages through wage-good prices. Estimated residuals, $\varepsilon^{c}_{i_t}$, in (1) are denoted $CO\text{-}RES_{i_t}$, for core sector residuals, or, akin to *controlled* core sector inflation.[13]

In Figures 1-3 it is noticeable that there has been an increased asymmetry in the cross-sectional density of inflation rates during recent years compared to earlier years. This finding is similar for π_{i_t}, $\pi^{c}_{i_t}$ and $CO\text{-}RES_{i_t}$, indicating possible upward mobility of core sector inflation rates, even after controlling for the indirect effects emanating from shocks to the food and energy sectors.

For a snapshot of unconditional changes in the distribution, the first three panels in Figure 4 summarize the evolution of annual π_{i_t}, $\pi^{c}_{i_t}$ and $CO\text{-}RES_{i_t}$. Panels (a), (b) and (c) are plots of annual weighted moments—mean, variance and skewness respectively—for the most recent 17 years. All three moments exhibit an upward trend after 1999/00. The skewness has increased for the density function for core sector inflation over the last decade or so (panel (c)). The weighted plots for controlled core sector inflation strongly confirm that observed changes in the skewness towards the right are not on account of food and energy prices. There are two instances of high right skewness of pdfs of $\pi^{c}_{i_t}$ and $CO\text{-}RES_{i_t}$, viz., 1998/99 and 2010/11. The more recent episode stands out because it is characterized by both high skewness and high inflation, unlike (i) the previous episode of high inflation in the mid-1990s that was not coincident with high skewness; and (ii) the high skewness in 1998/99 was characterized by moderate inflation (examining panels (a) and (c) of Figure 4 together). As observed earlier, it would seem that the current high inflation episode is stoking inflationary expectations in a more generalized manner.

The finding that accelerating overall inflation tends to increase the positive skew of the cross-sectional distribution is consistent with evidence cited elsewhere (for example, Blejer [1983]). One possible explanation of increasing rightward skew observed in recent years is that gradually capacity constraints are percolating through to sectors of the Indian economy. A plausible intuition is that diverse sectors had dissimilar "head room" at the onset of the upswing in the most recent business cycle, therefore sectors come to face capacity constraints at different times in response to nominal shocks.

Figure 1: KDFs for WPI-all



Note: The Indian fiscal year is April-March, hence 1995 refers to 1994/95, 2011 to 2010/11 etc. This is applicable to dates in all figures.

Figure 2: KDFs for Core Sectors

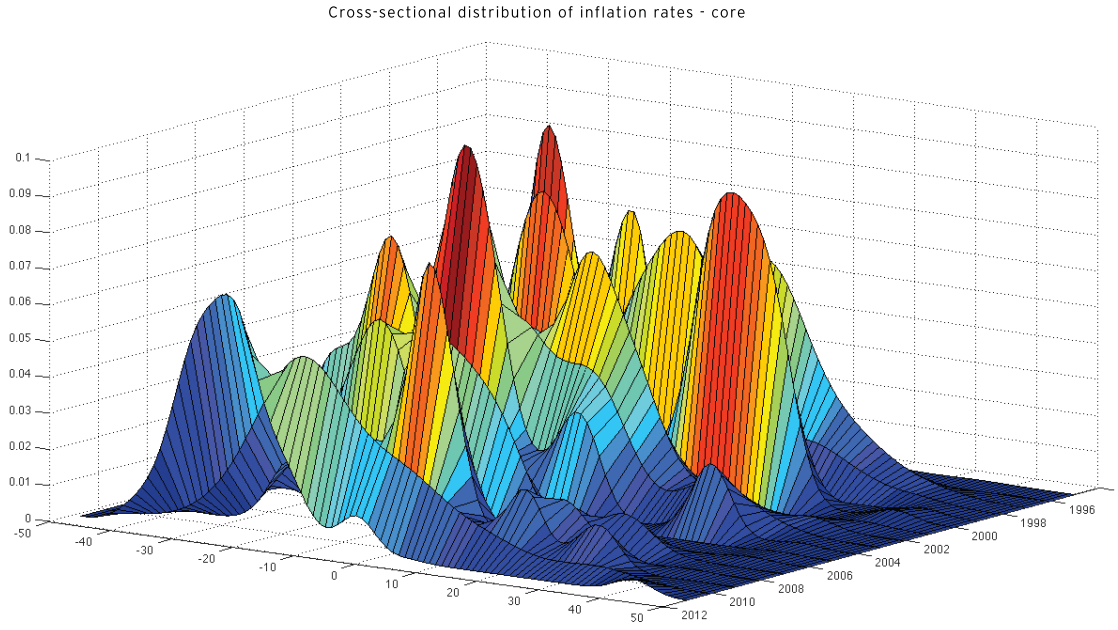


Figure 3: KDFs for CO-RES

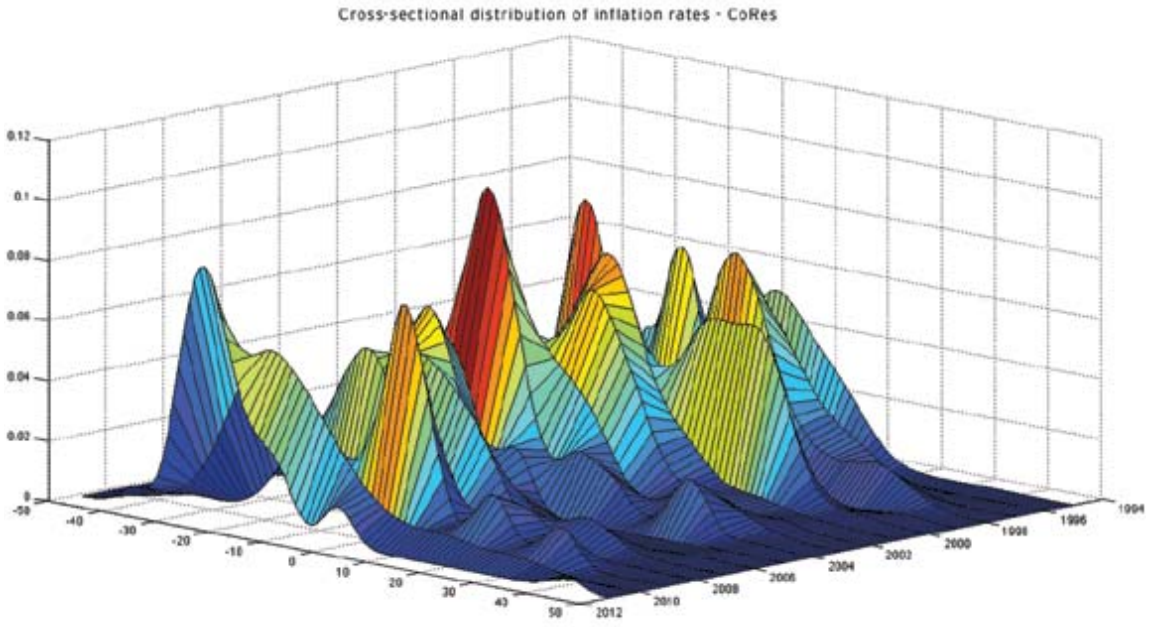
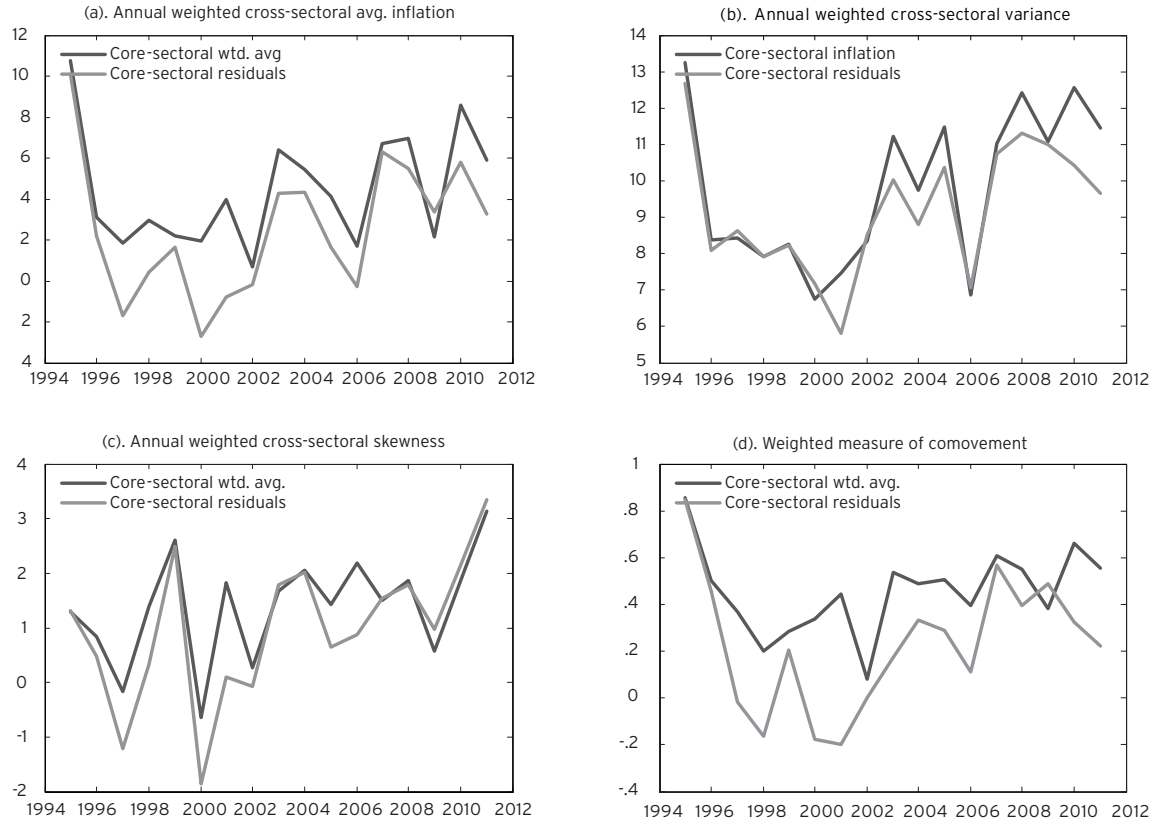


Figure 4: Snapshot of Unconditional Moments of pdfs



Taken together, our unconditional distribution analysis suggests that not only has India experienced high overall inflation in recent years, the tendency is permeating across an increasing number of sectors. Public pronouncements that one or two sectors are driving aggregate inflation are not borne out by the data distributions.

RESULTS: COMOVEMENT

We find that both weighted core sector inflation, π_t^{cw}, and weighted controlled core inflation, $CO\text{-}RES_t^w$, have comoved with aggregate inflation over the last decade, and after 2005/06 the comovement has been increasing (panel (d) of Figure 4). It is noteworthy that the high comovement in recent years was matched during the previous bout of high inflation in the mid-1990s (1994/95 and 1995/96). Formally, the estimated weighted measure of comovement confirms the "visual" identification of core sector inflation, controlled core sector inflation and aggregate inflation moving broadly together; the comovement statistic associated with core sector inflation is estimated at about 0.6 in the last couple of years, in comparison to 0.1 in 2002/03.[14]

Exploiting the motivation provided by New Classical and New Keynesian microeconomic approaches comprising of menu costs, asymmetric rigidities, trend inflation and monopolistic competition that differ across sectors, we directly examine the association between sectoral price changes and overall inflation in light of persistent and increasing skewness discerned in recent years from our KDF plots. In contrast to previous empirical attempts cited earlier that have considered this issue for other economies by emphasizing sources of overall inflation, we propose to directly appraise this link between core sector price changes and relative importance of sector specific aspects vis-à-vis overall economy wide aspects. We consider the following specification:

$$\pi_{i_t}^c = \alpha_i + \beta_i \text{ aggregate inflation}_t + \varepsilon_{i_t} \qquad (2)$$

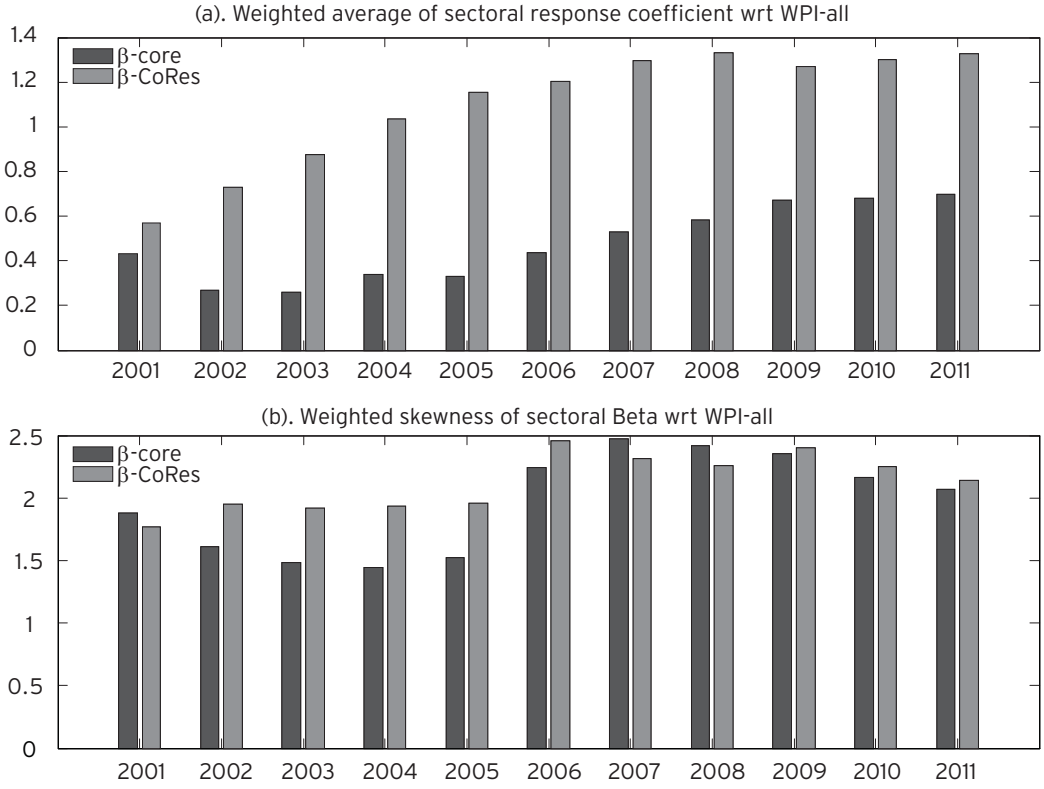
where $\pi_{i_t}^c$ is annual inflation of core sector *i* (=1,..., 54), in the WPI. The above "single factor" equation eschews *ad hoc* identification of macro variables, including expectations, in the price determination process.[15] In a sense, aggregate inflation is (not implausibly) taken to be a sufficient statistic to reflect all relevant fundamental macro information comprising fiscal-financial-monetary triggers/causes, outside of sector idiosyncratic components and shocks.[16] Price changes may be required either both because of structural shifts in sector-specific demand/cost function and/or due to a change in the general price level (Sheshinski and Weiss [1977]). The specification captures the notion that suppliers react to economy-wide market movements. (In an appeal to casual empiricism: it is not unusual to hear vendors say that his/her supply price has had to be increased because prices of "everything," related and unrelated to his/her sector, have been going up recently—a form of, what we call, inflation "herding".) α_i "captures" the importance of sector specific shocks to changes in price of sector i, and β_i is sector i's "response" to overall inflation, representing a common economy-wide factor.

To control for indirect effects of food and energy inflation as well, we also estimate the following analogue to (2):[17]

$$CO\text{-}RES_{i_t} = \alpha_i^{cr} + \beta_i^{cr} \text{ aggregate inflation}_t + \varepsilon_{i_t}^{cr} \qquad (3)$$

Since it is the dynamic evolution, or time variation, of underlying drivers of sector price changes that is of interest in consonance with the KDF plots of sectoral inflation presented in the previous section, we estimate equations (2) and (3) on a rolling window basis—over an in-period sample of 72 months, April 1994 to March 2000, and then roll, over a 12-month window, for the next 11 fiscal years up to March 2011. The weighted mean of the responses, β_is and β_i^{cr}s, is positive with an upward trend (upper panel of Figure 5). The weighted mean of β_is has risen particularly steeply after 2004/05 reaching 0.7 in 2010/11. The weighted average β_i^{cr}s exhibit an even more sustained upward trend since 2000/01—except for a slight decline in 2008/09—reaching a value of about 1.3 in 2010/11. After near

Figure 5: Response Coefficients



parity in 2000/01, the response of controlled core sector residuals rose faster and is substantially higher than of core sector inflation. In contrast, the weighted α_is and α_i^{cr}s(not shown) don't exhibit a trend and seem to vary around a mean of 0.2-0.25 for virtually the entire last decade. Regarding variability, neither for α_is and α_i^{cr}s nor for β_is and β_i^{cr}s are there unambiguous long term trends over this period.

Congruent with the findings on the weighted mean of core sector response coefficients, the weighted skewness for β_is and β_i^{cr}s also show a sharp increase between 2004/05 and 2006/07, with the measure staying at an elevated level thereafter, albeit showing a (slight) downward trend after 2008/09 (lower panel of Figure 5). The findings from application of equations (2) and (3), reinforced by the unconditional KDFs, imply that sector prices, along a wide swathe of commodities, are upwardly mobile with inflation becoming more broad, and that the price dynamics appear to be increasingly driven by common factors. If the inflation process was indeed driven by one or two critical sectors, as is being claimed by policy authorities for an inordinately long time, then one would not expect to find a rightward shift in the response coefficients for the cross-sectional inflation rates, $\pi_{i_t}^c$, and $CO\text{-}RES_{i_t}$, as well. The results of comovement and response coefficients, in our view, point to the emergence of generalized inflation expectations in the overall price determination process.

Role of Common Factors

Number and Importance of Common Factors

Having established *prima facie* evidence for increasing comovement across sector inflation rates in the previous section, we now turn to formally test for the presence and importance of common factors among sector inflation rates using the methodology of Dynamic Factor models.

In contrast to the "limited" "one-factor" analysis of the previous section, we postulate a multi-factor model for core sector inflation:[18]

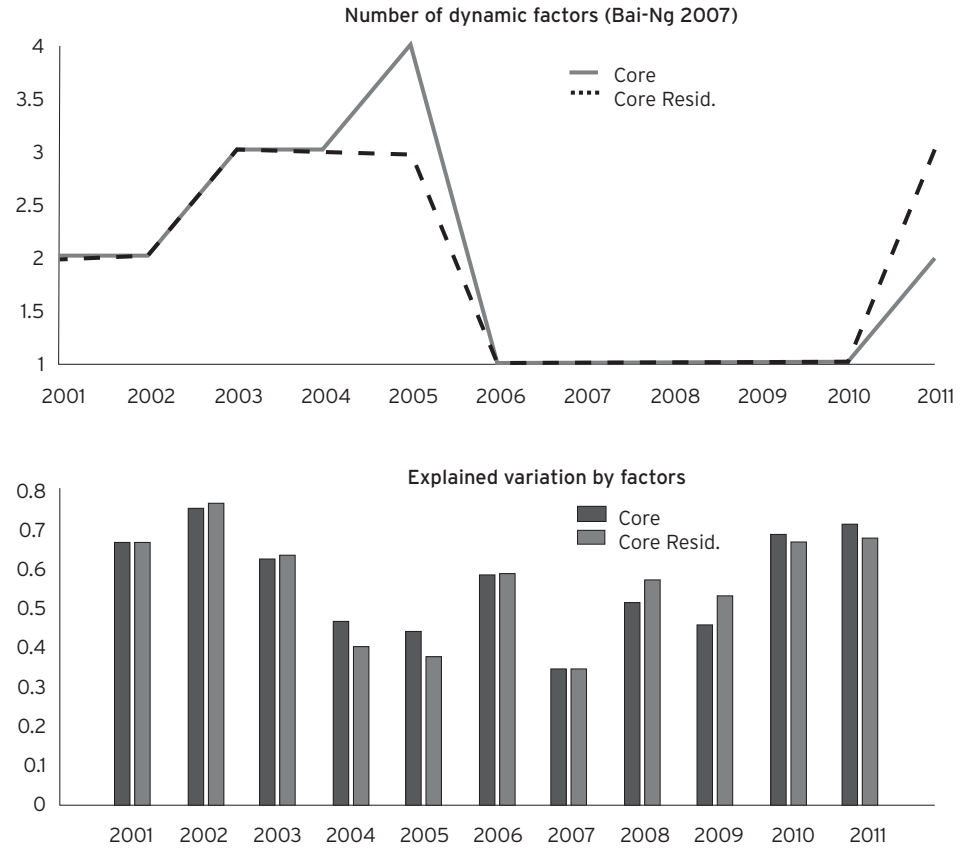
$$\pi^{c}_{it} = \Lambda_i' F_t + u_{it}, \; i = 1, ..., 54; \; t = 1, ..., T \qquad (4)$$

$$F_t = \Phi(L) F_{t-1} + v_t \qquad (5)$$

where F_t is (vector of k) unobserved factors common to (all or some) of the sectoral inflation rates (that is, they capture common sources of variation in prices), Λ is the set of $(n \times k)$ factor loadings indicating the sensitivity of sectoral inflation rates to common primitive shocks[19], while u_{it} $(n \times 1)$ is a remainder that captures good-specific variability associated with idiosyncratic sectoral events or measurement error. Whereas the relation between π^{c}_{it} and F_t is static, F_t itself can be a dynamic process (Bai and Ng [2008]).[20] Common sources of variations in prices might be on account of aggregate shocks affecting all sectors, like changes in aggregate productivity, government spending, or monetary policy, or they might be due to shocks that affect many but not all sectors, like changes in energy prices, weather events in agriculture—in other words, common factors may also comprise of sector shocks that ultimately turn out to be systemic—or exchange rate fluctuations and the price of tradables.[21] The optimal number of static or dynamic factors can be obtained using either a heuristic on the proportion of variation explained, as is typically done, or more formal methods.

We determine the rank of the spectral density matrix of the common components in the WPI for 54 non-food non-energy, core sector monthly series using the procedure of Bai and Ng [2002 and 2007] for the period 1994/95-1999/00 to formally determine the exact value of k, then use a 12-month rolling window up to March 2011 to ascertain the variation in the number of common factors over time (keeping in mind our objective of investigating how the empirical properties in the Indian inflationary process have evolved over time).[22] The results are summarized in Figure 6: the red curve in the upper panel of the figure plots the number of common factors and the blue bars in the lower panel plots R^2_t (explained variation or fraction of variance) up to March 2011. While the optimal number of factors has changed over time, the number stays within a narrow band. It is striking that core sector inflation in India is driven by a small number of factors—not more than three (except for one year) at any point in time over the last eleven years. This is consistent with well documented analysis of macroeconomic time series extensively investigated and referenced in, among others, Stock and Watson [2005] and Bai and Ng [2007] for the U.S. The small number of common factor(s) extracted from our extensive price sample account for a substantial proportion of fluctuations. Jointly assessing the two panels in Figure 6, it is noteworthy that during periods of multiple common factors, their coincident importance seems to be less compared to periods of a single (or two) dominant factor(s). For core sector inflation, over three years, 2007/08 to 2009/10, a single factor is generating about 50-70 percent of the variation. The explanatory power of this single factor in recent years is larger

Figure 6: Number of Dynamic Factors and Proportion of Variation Explained



on average than in the three years characterized by 3-4 common factors. During 2010/11 the number of common factors is two, and the explained variation is slightly higher.

For robustness, we obtain results estimated over a longer initial estimation period, viz., April 1994 to March 2004, and expand the sample up to March 2011 since it is accepted that the post-2004 period coincides with the recent high growth phase in India. Again, we find that a single dominant (generalized inflation) factor explains over 65 percent of the variation in inflation in recent years for the core sector commodity groups. (The single factor specification for linking sectoral inflation and overall inflation of the previous section appears to have been vindicated.) Taken together it would seem that there has been an increased comovement in inflation across sectors (engendered by fewer factors) over the last eight to ten quarters compared to previous years; the inflationary dynamics started to permeate widely and become more generalized over this period.

Does Food and Energy Inflation Drive Core Sector Inflation?

To answer the above question, we examine: (1) whether food and energy sectors span the common factor space of core sectors; and (2) the common factor dynamics of core sector inflation after controlling for the effects of food and energy price shocks.

Bai and Ng [2006] formally derive statistics that test whether latent factors underlying a set of economic variables are spanned by some other observed factors. Using the same framework, a finding that food and energy sector inflation does indeed span the common factors in core sector inflation can be construed as evidence in favor of the stance of the policy authorities that the former are the key drivers behind India's inflation experience. Rejection of such a null, on the other hand, would constitute important evidence against the widely held public (policy) belief about the role of food and energy sectors, and point towards some other drivers of the inflation process. Table 3 presents the test statistics *A(j)* (columns 2 and 3), Noise-to-Signal ratio, *NS(j)* (columns 4 and 5), and R^2 (columns 6 and 7) for rolling samples from 2000/01 to 2010/11. The *A(j)* statistics are substantially higher than 0.10, indicating the rejection of null of exact spanning, while the *NS(j)* and R^2 statistics indicate that the degree of spanning is weak at best with the exception of the last two years where one sees, to some extent, the importance of energy inflation in driving core sector inflation. Overall, the results indicate that food and energy sectors do not explain the latent or common factors underlying core sector inflation rates and that the explanation for the dynamics of core sector inflation will have to come from somewhere else.

To further eliminate higher-order effects of food and energy emanating from input-output considerations and supply shocks leading to wage-price linkages through wage-good prices, we also estimate the common factor structure on the controlled core sector residuals:

$$CO\text{-}RES_{i_t} = \Lambda_i' H_t + z_{i_t},\ i = 1, ..., 54;\ t = 1, ..., T. \qquad (6)$$

$$H_t = \Phi(L)H_{t-1} + \xi_t \qquad (7)$$

Reminiscent of core sector inflation, we find that between 2007/08 and 2009/10 a single factor is generating between 50 and 70 percent of the variation for controlled core sector residuals (see Figure 6—dashed blue curve in the upper panel and brown bars in the lower panel, respectively). The period 2002/03 to 2004/05 displays a precedent similar to that for $\pi^c_{i_t}$, although in the last year of the sample multiple factors are detected, with explained variation same as in 2009/10. During the period of multiple common factors (3), (2002/03 to 2004/05), a declining fraction of the variation is being explained. In summary, the finding that, on average, fewer common factors explain more of the variation in Indian core sector inflation is supported by the factor analysis on $CO\text{-}RES_{i_t}$.

The finding that fewer common factors explain a larger proportion of variation in sector inflation rates, combined with the results on comovement of the previous section, indicate an emerging consensus about trending inflation in the sectoral price determination process if these common factors are also found to be increasingly persistent. We turn to this issue in the next subsection.

Extent and Source of Inflation Persistence

It has been surmised that the current level of high inflation is explained by unrelenting supply side and international causes related to food and energy seg-

Table 3: Bai-Ng [2006] Tests on Common Factor Spanning

	A(j)		*NS(j)*		R^2	
Year	**Food**	**Energy**	**Food**	**Energy**	**Food**	**Energy**
2000/01	0.85	0.79	4.66	9.54	0.18	0.09
2001/02	0.85	0.92	5.75	8.70	0.15	0.10
2002/03	0.86	0.89	13.54	13.15	0.07	0.07
2003/04	0.86	0.83	15.45	12.14	0.06	0.08
2004/05	0.89	0.79	30.58	7.37	0.03	0.12
2005/06	0.75	0.56	6.42	1.88	0.13	0.35
2006/07	0.80	0.99	16.45	66.12	0.06	0.01
2007/08	0.79	0.70	11.02	3.82	0.08	0.21
2008/09	0.79	0.80	12.08	9.01	0.08	0.10
2009/10	0.94	0.58	22.91	1.25	0.04	0.45
2010/11	0.89	0.54	13.27	1.61	0.07	0.38

Note: A(j) is the frequency that the test for null of observed factors spanning latent factors exceeds the 5% asymptotic critical value. When it is less than 0.10, we cannot reject the null. NS(j) is the noise-to-signal ratio for jth observed factor projected on to extract the latent common factors, and R^2 is the coefficient of determination.

ments of the Indian economy. Further, it is these insistent narrow sectoral influences rather than extensive macro grounds, which are demand management and expectations driven, that are feeding through to broader measures of inflation through an input cost and/or wage-good price dynamic in a stubborn spiral. To understand this issue further, we estimate the extent and sources of persistence of inflation at the sectoral level. Analysis of sources of persistence of inflation—in terms of that of common factors and idiosyncratic factors—is of particular importance to the conduct of monetary policy. A finding, for example, of increasingly persistent common factors, rather than sector specific factors, driving sector level inflation persistence would support the presence of generalized expectations in the price determination process and shift the responsibility to macroeconomic policies.

In analyzing the degree of persistence in sector specific and common factors in inflation rates, we use two metrics: tests for the presence of *unit roots*, and an empirical *measure of persistence*. Following a tradition in the empirical inflation literature, we first test for the presence of unit roots in core sector inflation rates using the (univariate) DF-GLS method of Elliot, Rothenberg and Stock [1996]. The DF-GLS method is essentially an Augmented Dickey-Fuller test, i.e., $\Delta \pi^c_{it} = \rho\pi^c_{it-1} = K(L)\Delta\pi^c_{it-1} + \eta_t$ with the data being detrended with a GLS regression before performing the test.[23]

Column 2 in Table 4 presents the average (across the rolling windows through the years 1999/00 to 2010/11) of the t-statistic that tests for the null of unit root in the series for core sector inflation, π^c_{it}; the results clearly reject the null of unit root in about 95 percent of the groups, thereby implying that the (monthly sea-

Table 4: Results of Unit Root Tests on Inflation for Core Sector and CO-RES

Sector	Core sector	CO-RES
All Commodities	-4.30	
Food	-4.79	
Energy	-3.13	
Fibers (wt. 1.52)	-3.19	-2.75
Oil seeds (wt. 2.67)	-2.00	-2.02
Other non-food articles (wt. 1.95)	-3.40	-3.17
Metallic minerals (wt. 0.30)	-2.65*	-2.38*
Other minerals (wt. 0.19)	-3.28	-3.83
Dairy products (wt. 0.69)	-2.86	-2.75
Canning, preserving & processing of fish (wt. 0.05)	-2.29*	-2.23*
Grain mill products (wt. 1.03)	-2.39*	-2.41*
Bakery products (wt. 0.44)	-1.80*	-1.888
Sugar, khandsari & gur (wt. 3.93)	-3.55	-3.65
Manufacture of common salts (wt. 0.02)	-3.66	-2.58*
Cocoa chocolate sugar & confectionery (wt. 0.09)	-4.31	-4.17
Edible oils (wt. 2.76)	-4.60	-4.43
Oil cakes (wt. 1.42)	-3.24	-2.74
Tea & coffee processing (wt. 0.97)	-2.58	-2.13
Other food products n.e.c (wt. 0.15)	-2.79	-2.40
Wine industries (wt. 0.27)	-2.58*	-3.26
Malt liquor (wt. 0.04)	-3.81	-3.90
Soft drinks & carbonated water (wt. 0.05)	-2.40*	-2.33*
Manufacture of bidi, cigarettes, tobacco & zarda (wt. 0.97)	-4.06	-4.40
Cotton textiles (wt. 4.22)	-5.06	-5.36
Man-made textiles (wt. 4.72)	-4.65	-4.53
Woolen textiles (wt. 0.19)	-4.23	-3.78
Jute hemp & mesta textiles (wt. 0.38)	-4.52	-4.47
Hessian cloth (wt. 0.21)	-5.31	-4.97
Other misc. textiles (wt. 0.30)	-3.68	-2.24*
Paper & pulp (wt. 1.23)	-4.09	-4.01
Manufacture of board (wt. 0.24)	-2.64*	-2.54*
Printing & publishing of newspapers, periodicals etc. (wt. 0.58)	-3.52	-2.23*
Tyres & tubes (wt. 1.29)	-5.33	-5.06
Plastic products (wt. 0.94)	-3.64	-3.62
Other rubber & plastic products (wt. 0.17)	-4.30	-4.96
Basic heavy inorganic chemical (wt. 1.45)	-3.10	-3.41
Basic heavy organic chemical (wt. 0.45)	-2.77	-2.69
Fertilisers & pesticides (wt. 4.16).	-5.31	-4.48

Table 4: Results of Unit Root Tests on Inflation for Core Sector and CO-RES (cont.)

Sector	Core sector	CO-RES
Paints varnishes & lacquers (wt. 0.50)	-3.58	-4.09
Dyestuffs & indigo (wt. 0.17)	-4.11	-3.99
Drugs & medicines (wt. 2.53)	-4.14	-4.46
Perfumes, cosmetics, toiletries, etc. (wt. 0.98)	-3.13	-3.15
Turpentine, synthetic resins, plastic materials, etc. (wt. 0.75)	-4.02	-4.00
Matches, explosives & other chemicals n.e.c. (wt 0.94)	-3.04	-3.66
Structural clay products (wt. 0.23).	-3.63	-3.16
Glass, earthenware, chinaware & their products (wt. 0.24)	-4.41	-4.35
Cement (wt. 1.73)	-5.98	-3.80
Cement slate & graphite products (wt. 0.32)	-4.16	-3.89
Basic metals & alloys (wt. 6.21)	-6.74	-4.71
Non-ferrous metals (wt. 1.47)	-2.59*	-2.72*
Metal products (wt. 0.67)	-4.10	-2.92
Non-electrical machinery & parts (wt. 3.38)	-5.68	-3.66
Valve (wt all types) (wt. 0.09)	-4.48	-4.83
Electrical machinery (wt. 4.98)	-4.85	-3.66
Enameled copper wires (wt. 0.15)	-5.08	-3.82
Locomotives railway wagon & parts (wt. 0.32)	-5.80	-5.10
Motor vehicles, motorcycles, scooters, bicycles & parts (wt. 3.98)	-3.44	-3.23

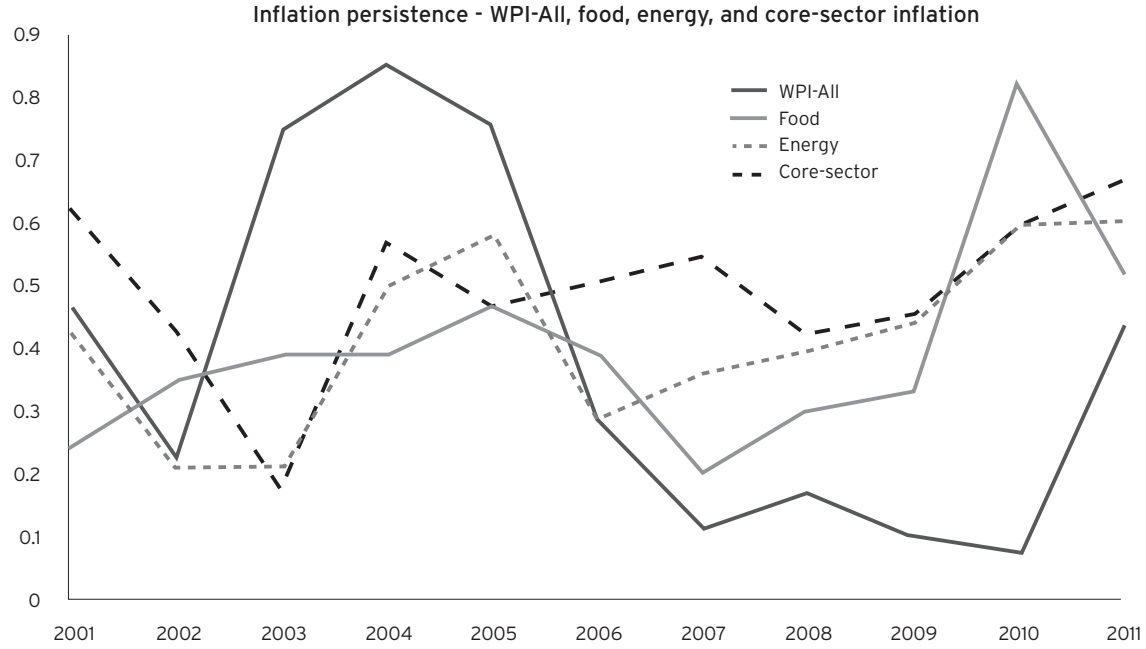
* *Denotes: Not significant at 5 percent critical values associated with optimal lag length.*

sonally unadjusted) core sectoral inflation process in India is stationary.[24] The results remain the same even after controlling for food and energy price effects (Column 3 in Table 4).

Rolling sample estimates of the sum of autoregressive coefficients, ρ, indicate that there is an increase in persistence in recent times across the board as reflected in the upward movement of cross-sectional weighted moments of ρ_{it} for core sectors. After 2004/05, while persistence of food inflation and, to some extent, energy inflation has been variable, for core sector inflation the estimates show a clear upward trend (Figure 7). Persistence of broader measures of inflation is not due to the behavior of food and energy price changes alone, therefore, the explanation lies somewhere else. Based on the findings that the core sector inflation rates are increasingly driven by common factors and are also progressively more persistent, we analyze whether the latter pattern is determined by ever more persistent common factors, or, by sector specific factors?

The basic factor framework for large dimensional panels used earlier in this section allows us to formally investigate this proposition using the framework of PANIC ("Panel Analysis of Non-stationarity in Idiosyncratic and Common Factors") developed in

Figure 7: Inflation Persistence



Bai and Ng [2004]. PANIC test procedures allows one to extract common and idiosyncratic factors from a panel of data in the first stage, and derive the diagnostics for testing for unit roots in extracted common and idiosyncratic factors in the second stage. Results presented in Table 5 indicate that one can strongly reject the null of unit root in both common factors and idiosyncratic factors for core sector, as well as controlled core sector residuals, for the rolling samples up to 2008/09, reinforcing the earlier findings that India's inflation process is devoid of a unit root. However, common factors for both groups display unit root behavior for 2009/10 and 2010/11. To obtain further insight into these dynamics, the extent of- and the time variation in- the persistence of common and sector specific factors is evaluated.

Figure 8 plots the average measures of persistence for common and sectoral factors obtained from estimates of equations (4) and (6). The time evolution of this measure[25] for common factors pertaining to core sector, π^{c}_{it}, shows that these have become more enduring in recent years; on the other hand, while idiosyncratic factors are persistent, there is no distinct change in the degree of their persistence (upper panel of Figure 8). Almost identical findings are obtained for estimates of the persistence of common and idiosyncratic factors relevant to $CO\text{-}RES_{i_t}$ (lower panel of Figure 8).

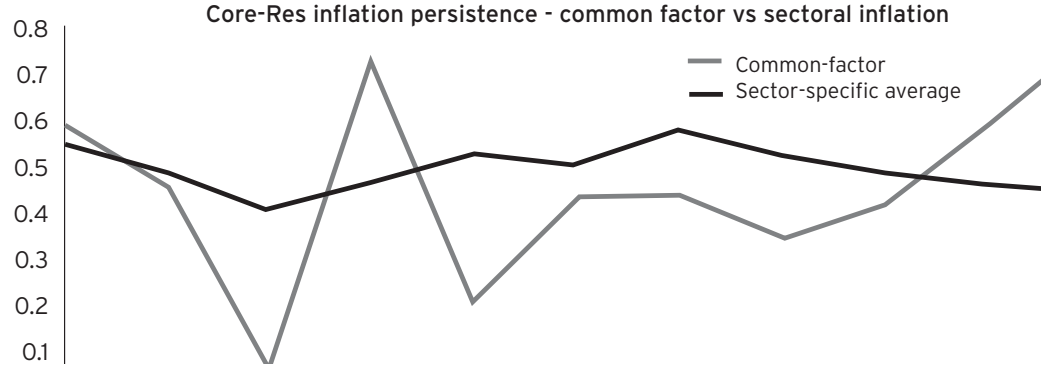
It is clear that in recent years (2008/09 to 2010/11), for the most part, a small number of common factors are found to be far more durable in the inflation dynamic rather than sector specific pressures. India's

Table 5: PANIC Test on Inflation

	Core sector		CO-RES	
Year	CF-UR	IS-pool-UR	CF-UR	IS-pool-UR
2000/01	-1.94	-2.77	-2.00	-2.94
2001/02	-3.18	-3.38	-2.74	-3.20
2002/03	-7.11	-3.12	-5.29	-4.03
2003/04	-2.19	-2.98	-1.50	-3.03
2004/05	-3.00	-2.94	-2.98	-2.88
2005/06	-2.79	-3.00	-3.30	-2.78
2006/07	-2.49	-3.01	-4.25	-2.72
2007/08	-4.39	-3.12	-3.65	-2.74
2008/09	-3.01	-3.17	-3.33	-2.91
2009/10	-1.87*	-2.96	-1.63*	-3.12
2010/11	-1.83*	-3.11	-1.44*	-3.40

*Notes: * Denotes: Not significant at 5 percent level (critical value is 1.96). CF: common factor; IF: idiosyncratic factor; UR: unit root.*

Figure 8: Core Sector Inflation Persistence – Common Factors vs Idiosyncratic Factors



most recent flirtation with high core sector inflation is likely to be difficult to rein in, regardless of the identity of the common factors driving the process. If policy makers had formally investigated the change in the degree of persistence we would have been spared the optimistic "rolling forecasts" alluded to in the introduction.

Our results in this subsection convey that while India's recent inflationary experience does not follow a unit root process, in recent times the dynamic is characterized by increasing persistence. The common factors underlying this wide ranging (across sectors) manifestation has been exhibiting a similar—increasingly "headstrong"—and possibly disturbing trait (from the standpoint of prospective policy effectiveness). These findings collectively suggest that bringing inflation down to "acceptable" levels *at this (overdue) stage* is likely to be an onerous task for policy makers.

PURE INFLATION GAUGES (PIGS) AS A MEASURE OF POLICY (IN-) EFFECTIVENESS

An important prerequisite for the effective conduct of monetary policy in targeting inflation is to identify the aggregate source of changes in commodity prices. While an undue amount of effort is placed on identifying the sources of variation in aggregate or headline inflation—in terms of macroeconomic impulses, critical sector specific supply side shocks, etc. usually through VAR and related methods—very little work has been done in exploring the significance of aggregate or common factors in explaining the variation in disaggregated sectoral inflation. Understanding the sources of variation in inflation at a sectoral level is important for two reasons. First, sectoral inflation as against aggregate inflation is more closely associated with the welfare effects of macro or monetary policies. Second, it helps to understand how much of observed variation in sector inflation rates is due to economy wide aggregate factors reflecting, *inter alia*, generalized inflation expectations or sector specific idiosyncratic factors. Decomposing sectoral price variations into those associated with common (macro) factors, as against sector specific factors, can provide a better indication of the effectiveness of macro and monetary policies in containing inflationary pressures than measures of headline inflation that are prone to well known aggregation biases.

Constructed aggregate indices such as WPI-all may not reflect the correlation and response of goods prices with respect to aggregate source(s) and, being an (weighted) average of disaggregated prices, indices may be unduly influenced by select commodity groups. Various methods, for example trimmed means, were developed to construct a core inflation measure that is less sensitive to outliers in underlying disaggregated data. While these methods provide statistically robust measures of aggregate inflation, they do not correspond to a notion of aggregate inflation that is common to all disaggregated groups (Bryan *et. al.* [1997]). More specifically, no economic interpretation can be attached to such measures as we can do with the common factors driving the panel of disaggregated inflation.

In order to understand to what extent the observed sectoral price changes are driven by aggregate factors, that have equiproportional or differential effect on all or some of commodity groups, and sector specific factors, we specify that sectoral inflation rates can be decomposed into three components: (i) a *pure inflation* component that affects all commodity groups equiproportionately; (ii) *aggregated relative inflation* components that affect some commodity groups more than others; and (iii) *idiosyncratic* components that are sector specific, that is:

$$\pi_{i_t} = a_t + \Lambda_i' F_t + u_{i_t},\ i = 1, ..., 63;\ t = 1, ..., T. \qquad (8)$$

where π_{i_t} are measured sector inflation rates (in WPI-all); a_t is the *pure inflation* factor, which has equiproportional effects on all sectoral price changes and, by construction, is orthogonal to (aggregated) relative price factors and *idiosyncratic* factors. F_t is the vector of (aggregated) relative price factors, Λ is the matrix of common factor loadings and u_{i_t} represent the sector specific components of inflation. This decomposition can be interpreted either as a time series of cross-sectional distribution of inflation rates, or a cross section of time series of each of the sector specific inflation rates.

We label a_t "pure" because, by construction, its changes are uncorrelated with relative price changes at any point in time. In a simple flexible-price classical model where money is neutral, pure inflation would equal the money growth rate. More generally, it cor-

responds to the famous thought experiment that economists have used since Hume (1752): "imagine that all prices increase in the same proportion, but no relative price changes". Measurement of *pure inflation* from the disaggregated sectoral inflation rates, which may not be similar to that based on WPI-all, will help us answer two important questions: (i) to what extent is the observed variation in sectoral prices due to idiosyncratic or sector specific factors as against "pure" or correlated relative price shocks; and (ii) is there an increase in the pure inflation component in recent times indicating an increase in generalized inflationary expectations due to—not implausibly—lax macroeconomic management or accommodative monetary policies.

Methodology for Measuring PIGs

Following the cross-sectional regression approach of Fama and MacBeth [1973] in the empirical asset pricing literature, we postulate that the cross-sectional distribution of disaggregated sector inflation rates can, at any given time period, be explained by the sensitivities of each sector to aggregate or sub-aggregate shocks, sector specific shocks and a common shock, i.e.,

$$\pi_{i_{t+h}} = a_t + \gamma_t \Lambda + \eta_i,\ i = 1, ..., 63;\ t = 1, ..., T. \qquad (9)$$

where the variables are as defined above.

We follow a two-stage procedure for implementing this approach:[26]

1. At the first stage, we estimate, Λ the factor sensitivity matrix or factor loadings, by undertaking a principal component analysis on the panel of inflation rates π_{i_t} measured up to time *t* using the relation $\pi_{i_t} = a_t + \Lambda_i' F_t + u_{i_t}$.

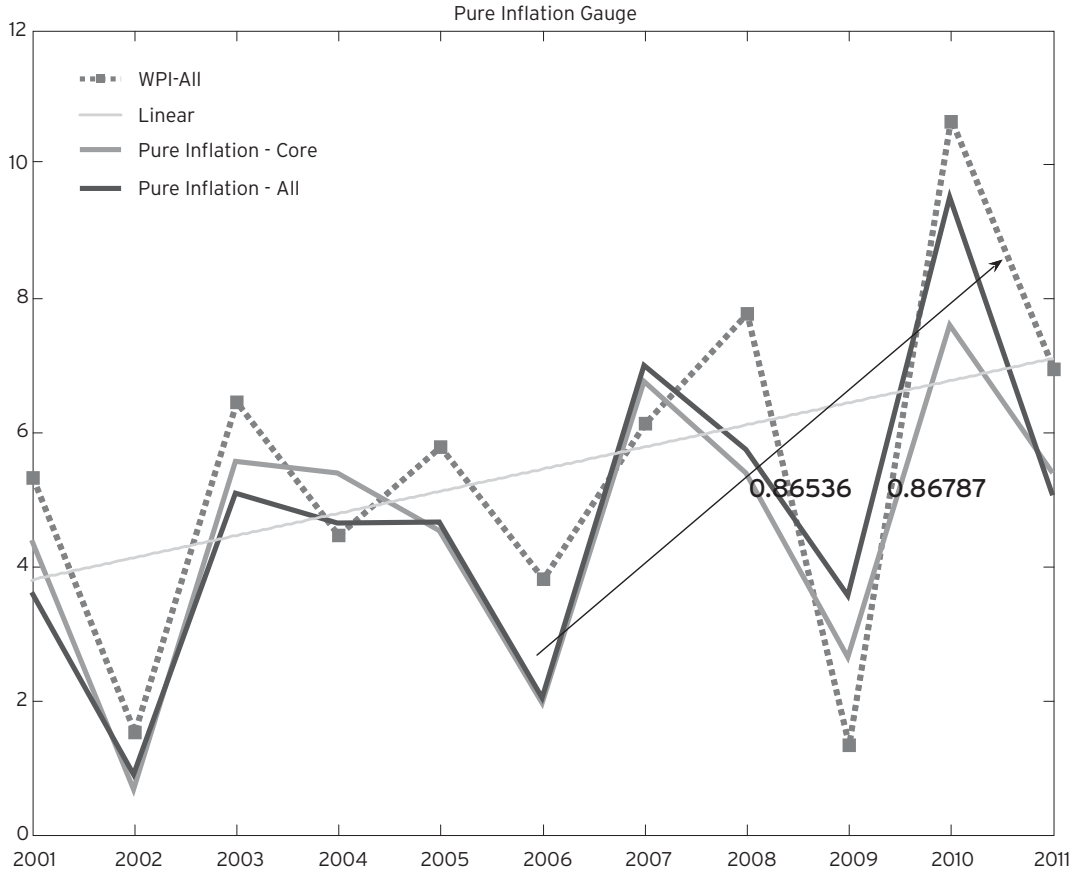
2. At the second stage, we regress cross-sectoral inflation rates for time period *t+1* on the estimated factor sensitivities from stage 1, i.e., $\pi_{i_t} = a + \gamma\Lambda + \eta_i$. The intercept term in this cross section regression, as explained above, is *pure inflation* for period *t+1*.

3. This procedure is repeated for all *t+h*, *h* = 1...T, and the time series of *pure inflation* are extracted as a_{t+h}.

The cross-sectional approach to the measurement of *pure inflation* is particularly useful since it can easily be modified to include other factors influencing cross-sectional differences in inflation rates, thereby making the estimate of *pure inflation* relatively more robust. There are concerns with the methodology. First, the factor sensitivities that we use as control variables in the second stage regression are unobservable and hence have to be estimated from the first stage time series model, which introduces an errors-in-variables problem. To mitigate this problem, as suggested by Fama and MacBeth [1973] in the context of the CAPM[27], we use sub-aggregate indices of inflation rather than the most detailed commodity level inflation rates. Also, the errors-in-variables problem has consequences for the inference related to the slope coefficients in the second stage regression and much less effect on the point estimate of the intercept term, i.e. the *pure inflation* term in the present context, which is the focus of our exercise.

In Figure 9, we overlay on WPI headline inflation for the April 2001 to March 2011 period, pure inflation gauges (PIGs) extracted from aggregate inflation (pure-all) and core sector inflation (pure-core).[28] While, like most measures of inflation in India, the three series are highly variable, the variability of pure-core is the least, with headline inflation as the most variable and pure-all in between the other two series. Both pure-all and pure-core are highly correlated with

Figure 9: PIGs



overall inflation—coefficients of around 0.9—but the differences between the three series in the figure are eye-catching. The most recent trough in headline inflation may have given policy makers false indication of muted underlying inflationary pressure. While aggregate inflation by the end of 2008/09 had declined to about 1 percent (from about 8 percent in 2007/08), pure-all and pure-core were running at, respectively, 3.5 percent and 2.6 percent (in contrast to the headline inflation, the most recent trough for pure-core and pure-all was 2005/06 and not 2008/09). The decline in (and the level of) headline inflation in 2008/09 may have conveyed to the authorities that they had more elbow room for monetary easing (or less need/more time for tightening) than was the case looking at inflation measures corrected for sectoral and idiosyncratic shocks. The steep decrease in aggregate inflation (with even talk of generalized deflation) may have informed the hasten-slowly ("lack of alacrity") strategy of the RBI; the resultant extended period of softer-than-warranted policy allowed inflationary expectations to take hold (since pure-all inflation, while

declining, was running at or near the upper end of the erstwhile policy comfort zone). The ensuing most recent period of high inflation followed, with headline inflation staying stubbornly in the 7-11 percent range, and even pure-core in excess of 5 percent, for most of the last two years.

If PIGs, in conjunction with our other findings, for example, on persistence had been used as a measure of underlying (pure) inflationary pressures, the monetary authorities may not have been sanguine regarding the timeliness of initiating anti-inflationary policies.

CONCLUSIONS

In the context of public discourse about inflation it is often the case that a few critical sectors are singled out as drivers of overall inflation. Typically, these factors are claimed by policy makers to be outside their purview, thus absolving themselves—at least partially –from the responsibility of inflation control. In this paper we propose a consistent empirical framework to validate such claims. Based on the analysis of a large panel of sector level inflation rates we attempted to determine how the empirical properties of the Indian inflationary dynamic have evolved over the last decade. We sought to impart methodological rigor along a four dimensional metric, viz., KDFs, comovement, persistence, and untangling aggregate inflation into "pure" and correlated components, which can be part of the operational tool kit for inflation management.

Overall our findings allow us to make the following statement: the recent bout of high, persistent and widespread (across sectors) inflation is not on account of food and energy. Firstly, we find that the extant bout of elevated inflation is coincident with right skewness of pdfs of sectoral prices. This is unlike the previous episode of high inflation in the mid-1990s, which was not characterized by large right skewness. Secondly, the pattern of inflation in the current period suggests that it has diffused widely across sectors, that is, there is increasing comovement measured by both intuitive "single factor" methods and from deploying somewhat intricate generic methods like dynamic factor analysis. Thirdly, the number of statistically identified common factors has declined since 2004/05, and these explain a larger fraction of the variation in inflation. Fourthly, recent times are characterized by increasing persistence of overall and core sector inflation. Fifthly, persistence of common factors has increased in recent years; while specific factors are persistent there is no distinct change in the degree over this period. All this is likely to make it more difficult for anti-inflationary policy to gain traction this time round compared to the past. It may have dawned somewhat late on the RBI that the underlying drivers were getting more stubborn, hence the recent robust hikes in policy interest rates that have been out of character from earlier behavior. Lastly, we find that if policy makers had used a pure inflation measure (PIGs) they would not have underestimated the underlying inflation in 2008/09, which informed their policy stance for rather too long.

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APPENDIX: LIST OF COMMODITY GROUPS

S. No	Commodity groups	classification
1	Basic heavy inorganic chemical (wt. 1.45)	core
2	Basic metals & alloys (wt. 6.21)	core
3	Cotton textiles (wt. 4.22)	core
4	Dairy products (wt. 0.69)	core
5	Fibers (wt. 1.52)	core
6	Locomotives railway wagon & parts (wt. 0.32)	core
7	Metallic minerals (wt. 0.30)	core
8	Paper & pulp (wt. 1.23)	core
9	Structural clay products (wt. 0.23)	core
10	Tyres & tubes (wt. 1.29)	core
11	Wine industries (wt. 0.27)	core
12	Basic heavy organic chemical (wt. 0.45)	core
13	Canning, preserving & processing of fish (wt. 0.05)	core
14	Glass, earthenware, chinaware & their products (wt. 0.24)	core
15	Malt liquor (wt. 0.04)	core
16	Man-made textiles (wt. 4.72)	core
17	Manufacture of board (wt. 0.24)	core
18	Motor vehicles, motorcycles, scooters, bicycles & parts (wt 3.98)	core
19	Non-ferrous metals (wt. 1.47)	core
20	Oil seeds (wt. 2.67)	core
21	Other minerals (wt. 0.19)	core
22	Plastic products (wt. 0.94)	core
23	Enameled copper wires (wt. 0.15)	core
24	Hessian cloth (wt. 0.21)	core
25	Valve (wt all types) (wt. 0.09)	core
26	Cement (wt. 1.73)	core
27	Fertilizers & pesticides (wt. 4.16)	core
28	Grain mill products (wt. 1.03)	core
29	Metal products (wt. 0.67)	core
30	Other non-food articles (wt. 1.95)	core
31	Other rubber & plastic products (wt. 0.17)	core
32	Printing & publishing of newspapers, periodicals etc. (wt. 0.58)	core
33	Soft drinks & carbonated water (wt. 0.05)	core
34	Woolen textiles (wt. 0.19)	core
35	Non-electrical machinery & parts (wt. 3.38)	core
36	Bakery products (wt. 0.44)	core

APPENDIX: LIST OF COMMODITY GROUPS (CONT.)

S. No	Commodity groups	classification
37	Cement slate & graphite products (wt. 0.32)	core
38	Jute hemp & mesta textiles (wt. 0.38)	core
39	Manufacture of bidi, cigarettes, tobacco & zarda (wt. 0.97)	core
40	Paints varnishes & lacquers (wt. 0.50)	core
41	Electrical machinery (wt. 4.98)	core
42	Dyestuffs & indigo (wt. 0.17)	core
43	Other misc. textiles (wt. 0.30)	core
44	Sugar, khandsari & gur (wt. 3.93)	core
45	Drugs & medicines (wt. 2.53)	core
46	Manufacture of common salts (wt. 0.02)	core
47	Cocoa chocolate sugar & confectionery (wt. 0.09)	core
48	Perfumes, cosmetics, toiletries, etc. (wt. 0.98)	core
49	Edible oils (wt. 2.76)	core
50	Turpentine, synthetic resins, plastic materials, etc. (wt. 0.75)	core
51	Matches, explosives & other chemicals n.e.c (wt. 0.94)	core
52	Oil cakes (wt. 1.42)	core
53	Tea & coffee processing (wt. 0.97)	core
54	Other food products n.e.c (wt .0.15)	core
55	Food grains (wt. 5.01)	food
56	Fruits & vegetables (wt. 2.92)	food
57	Milk (wt. 4.37)	food
58	Eggs, meat & fish (wt. 2.21)	food
59	Condiments & spices (wt. 0.66)	food
60	Other food articles (wt. 0.24)	food
61	Coal mining (wt. 1.75)	energy
62	Mineral oils (wt. 6.99)	energy
63	Electricity (wt. 5.48)	energy

**wt.: refers to weight in percent.*

ENDNOTES

1. The average WPI inflation rate for the current fiscal year is being projected by some respectable analysts to be as high as 8.5 percent.
2. Brazil, Russia, India, and China.
3. For example, the Report of the Committee on Capital Account Convertibility, May 1997.
4. The government manages to borrow at negative rates despite eleven policy rate hikes (aggregating 475 basis points) by the RBI since March 2010.
5. In September 1994 an agreement (without legislated sanction) to phase out by 1997/98 the instrument of *ad hoc* Treasury Bills which hitherto facilitated automatic monetisation of the budget deficit—the borrowing gap after all other financing instruments have been exhausted—was reached between the RBI and the Central Exchequer. This, in itself, did not preclude the RBI from participating in primary issues of central government securities or operating in the secondary markets for central government debt, but it left these decisions to the RBI's discretion.
6. For developed economies, research on inflation dynamics is dominated by the Phillips curve relationship (see Ball and Mazumder [2011] and references therein for recent examples).
7. The most glaring shortcoming is the coverage—while 55 percent of India's GDP is on account of services, the WPI ignores it! Also, see Srinivasan [2008].
8. Common factors (sources) can be likened to the macro policy backdrop (determinants) for changes in (all) inflation measures over time, or, they might be due to shocks that directly affect many but not all sectors, like changes in energy prices.
9. Menu costs can also be interpreted as reflecting the costs which are required to eliminate the uncertainty *on behalf of consumers* concerning changes in relative (in contrast to aggregate) prices.
10. The Indian fiscal year is April-March.
11. The list of commodity groups is provided in the Appendix at the end of the paper.
12. Month-on-month inflation, annualized for the purpose of scaling.
13. After trying out various lag lengths in (1), we have used $l = 6$ to obtain ε_{it}^{c} since beyond this lag length there is little change in our results.
14. Comovement is measured with respect to an aggregate, for example, comovement between core sector inflation and aggregate (headline) inflation at t is: $cm^{c\text{-}all} = \sum_{i=1}^{n} w_i \left((\pi_i^c \times \pi^{all}) / (|\pi_i^c \times \pi^{all}|)\right)$, with w_i denoting weight of commodity i (= 1,...., n), and $cm^{c\text{-}all} \in [-1, 1]$. The analogue for comovement between aggregate inflation and controlled core sector residuals, *CO-RES*, should be obvious enough.
15. The specification is analogous to models of asset pricing used to assess the cross-sectional dispersion of the factor sensitivity of assets within a given market, where the market index itself is deployed to "bifurcate" asset returns attributable to herding and (firm/sector) fundamentals (Hwang and Salmon [2004]).
16. "I think that there is a general fiscal-financial-monetary cause of inflation which essentially overrides all other considerations. Put another way: I do not believe that, in the longer run, the general price level is determined by the sum of its parts....The relationship between the price of steel, for example, and the price of wheat is a relative concept—that is, it is determined by the relative supplies and demands, and the absolute price of each is not determined by that relationship, but by the aggregate price level....." (Alan Greenspan quoted in Vining and Elwertowski [1976]).
17. Alternatively, we could have estimated (2) by deploying (separately) two auxiliary re-

gressors—food inflation and energy inflation—in addition to aggregate inflation, viz., $\pi^{c}_{it} = \alpha_i + \beta_{1_i}$ overall inflation$_t$ + β_{2_i} food inflation$_t$ + β_{3_i} energy inflation+ ε_{i_t}

18. The central foundation of the (dynamic) factor model is that there are a small number of unobserved common dynamic factors that produce the observed comovements of economic time series. These common dynamic factors are driven by common structural economic shocks, which are the relevant shocks that must be identified for the purposes of conducting policy analysis.
19. Akin to betas in the APT.
20. A dynamic factor model always has a static factor representation.
21. The application of factor estimates to summarise information in a data-rich environment has been found to be valuable in forecasting exercises and in the conduct of policy (Stock and Watson [2002] and Bernanke and Boivin [2001]).
22. An expanding window rather than a rolling window approach is used as more data points become available and, hence, more precision is obtained.
23. The null of unit root is a test on $\rho = 0$ as against the alternative of $\rho < 0$ with the choice of lag length based on MAIC for each series (Ng and Perron [2001]).
24. Other studies have found year-on-year inflation to contain a unit root, which, in our view, is an artifact of the temporal aggregation involved.
25. When multiple common factors are found, the measure of persistence is the weighted average of persistence of each individual common factor with weights being the proportion of variation attributed to each of the common factors.
26. Chowdhry, Roll and Xia [2005] follow a similar approach to estimate the *risk free* rate and the implied inflation rate from a cross section of stock returns. Reis and Watson [2010], on the other hand, use the dynamic factor formulation to estimate the *pure inflation* component in a single step.
27. Capital Asset Pricing Model.
28. The methodology for calculating pure-core is identical as that enunciated above for pure-all, but would cover 54 sectors.

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