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Abstract

This study examines whether skewness of the cross sectional distribution of relative price changes is positively associated with aggregate inflation as predicted by the Menu cost model of Ball and Mankiw (1994, 1995). Further, the study examines the size and frequency of price changes across various commodities and the distribution of relative price changes. The results from highly disaggregated Indian Wholesale Price Index data suggest that the skewness of relative price changes explains a significant proportion of short-run fluctuations in aggregate inflation. More importantly, the results indicate that the average size of price increases is greater than the size of price decreases implying downward rigidity in the prices of various commodities.

Keywords: *Inflation, Skewness, Relative price changes, Menu cost*
JEL Codes: *E30; E31; E52*

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INTRODUCTION

It is widely believed that rate of inflation in the long run is primarily determined by growth rate of money supply in an economy. However, the short run dynamics of inflation is more complicated in nature. The past experience of inflation shows that the rate of inflation fluctuates around its underlying trend in the short-run. These short-run movements of inflation reflect not only the changes in aggregate factors demand but also fluctuations in supply from various sectors of an economy.[1] Nonetheless, in presence of effective demand stabilisation policies, the short-run fluctuations in rate of inflation are mainly attributed to supply side factors. Thus, it is widely believed that shocks in the supply of few commodities in an economy impart transitory deviations to headline inflation (Mishkin, 2007).

Fundamentally, as argued by Ball and Mankiw (1994), supply shocks are changes in the relative prices of certain commodities. For example, a supply shock arising from crop failures will lead to rise in the relative prices of primary articles. On the other hand, positive supply shocks such as a good harvest reduces the relative prices of such articles. In Classical framework such changes in relative prices should not affect aggregate inflation (Friedman, 1975). Under Classical framework, the growth rate in money supply determine the aggregate price and changes in real factors determines the relative prices (Dornbusch and Fischer, 1990). Thus, for a given money stock, adjustments in relative prices are accomplished through increases in some nominal prices and decreases in others. Hence actual upward and downward adjustments in prices cancel out each other and the aggregate price level, which is measured as an average of individual prices, remains same. In the terms of Quantity theory ($MV = PY$), if M, V, and Y remain constant, then P is constant, and any shifts in the distribution of relative prices do not influence the

[1] A detailed discussion on the effects of aggregate demand and supply shocks on the inflation is provided by Naveen, Mahambare and Ramachandran (2006).

aggregate price level (Friedman, 1987). Under these conditions, there is no obvious reason for why aggregate inflation should be influenced by changes in relative prices of certain commodities. However, in contrary to this Classical belief, the empirical literature at large support the proposition that fluctuations in the relative prices do influence the aggregate inflation (see, e.g., Vinning and Elwertowski, 1976; Phelps, 1978; and Blinder, 1982).

Ball and Mankiw (1994, 1995) took different approach to provide theoretical explanation for how fluctuations in the relative prices of certain commodities such as food and energy are transmitted to aggregate inflation. They argue that firms face menu costs (i.e., a cost involved in changing the price, which include costs involved in deciding about new prices, communicating new prices, printing new menus, changing price tags, etc.) when they adjust their prices. In presence of menu costs, when a firm experiences a shock to its desired price, it changes its actual price only if the desired adjustment is large enough to warrant paying the menu cost.[2] This implies that firms respond to large shocks but not to small ones. In this setting, the nominal prices that face large shocks change and others which face small ones do not, as a result the overall price level changes. Therefore, large shocks have disproportionately large impact on the changes in aggregate price level in the short run.

One implication of such price adjusting behaviour connotes that changes in the aggregate price level and skewness of cross sectional distribution of relative price changes are positively associated The intuition behind this is that the skewness in the distribution of desired price change results in skewed distribution of realized/actual price changes as firms respond only (or more quickly) to large shocks than to

[2] Ball and Mankiw (1994) examined the price adjustment of firms while combining both state-contingent and time-contingent pricing. That is a firm is expected to adjust prices at regular as well as in between regular intervals when a firm is buffeted with a shock.

small ones. In this setting, an increase in the skewness of positively (negatively) skewed distribution of relative price changes leads to rise (fall) in the aggregate inflation and vice-versa.

In literature large number of empirical studies have provided evidence in favor of positive relationship between the skewness of the cross sectional distribution of relative price changes and the aggregate inflation rate (see, e.g., Ball and Mankiw, 1995; Amano and Macklem, 1997; Dopke and Pierdzioch, 2000; Aucremanne et al., 2002; Caraballo and Usabiaga, 2004; and Assarsson, 2004).[3] These results stand in contrast to the findings of Holly (1997) who finds that the skewness of the distribution of relative price changes does not exert a strong impact on the average inflation rate. More recently Pou and Debus (2008), extending the literature on this relationship, found that inflation and skewness relationship depends on the inflationary history of the country and thus may vary across countries. The ambiguity in the findings reported in existing empirical studies motivates the analyses carried out in this study. Further, to our knowledge, there is no study that examines this relationship in the context of an emerging economy. In this backdrop, this study examines the relationship between aggregate inflation and skewness using the data on Wholesale Price Index from India. In addition to this, the study examines the size and frequency price changes across various commodities and the distribution of relative price changes. The rest of the paper is organised as follows. In Section 2, a detailed discussion on various theoretical perspectives underlying this relationship is provided. Section 3 provides the description about the data and the methodology used. In Section 4, the empirical results are presented and finally the concluding remarks are provided in Section 5 of the paper.

[3] Number of studies extended this literature by empirically examining the reliability of skewness as an alternative measure of supply shocks, see e.g., Catik et. al. (2010); Caraballo et al., (2006).

THEORETICAL FRAMEWORK

Ball and Mankiw (1994, 1995) assume an economy composed of a large number of price-setting firms which adjust the prices of their on a regular basis and can also make special price adjustments between these regular adjustments in the wake of a shock. Further, they assume that to make such special adjustment firms need to pay menu cost that is the costs involved in adjusting the prices. They argue that under these conditions, when a particular firm faces a shock that changes its optimal price, the response of a firm depends on the magnitude of such shocks. If a shock is small in size, the firm does not respond and prefer to choose inaction as the benefits associated with changing the price does not outweigh costs associated with changing the price. However, a firm responds by adjusting its price if the shock is large enough that the loss incurred by failing to adjust is larger than the menu cost it pays. Such price setting behavior implies that the fluctuations in aggregate inflation largely depend on the variations in the skewness of cross sectional distribution of relative price shocks.

Following Amano and Macklem (1997), the price adjustments of firms is discussed under two different situations. First, when there does not exist trend inflation and the firms face the shocks which are not symmetrically distributed across firms. Second, there exist trend in inflation but the firms face shocks that are symmetrically distributed. For simplicity, only these two situations are assumed, however, in the real world firm faces both the trend inflation and asymmetrically distributed shocks simultaneously.

Asymmetric Shocks with No Trend Inflation

To examine price adjustments in a static model, Ball and Mankiw (1995) assumed that the distribution of shocks to desired prices is skewed with zero mean. In other words, the cross sectional shocks are assumed to follow skew normal distribution. This implies that if all the prices are adjusted perfectly both upward and downward, irrespective of size and sign of shocks, the average price level will not change. However, in presence of menu cost, when a firm faces shock to its desired price, it will change its price only if the costs of deviating from its new desired price exceeds the menu costs. An optimizing firm will not change its price in a situation where menu cost exceeds the benefits associated with changing the price. Therefore, a firm will choose inaction for certain range of shocks and will respond only to shocks which push the firm's desired price beyond certain level in either direction. Thus, under these circumstances, the response of a firm to a particular shock depends on the magnitude of a shock that a particular firm faces. In presence of such price adjustment, the asymmetry in the distribution shocks results skewed distribution of actual or realized price changes. That is higher (lower) skewness in the distribution of shocks results in highly (moderately) skewed distribution of actual price changes. The crucial implication of such pricing behavior is that the aggregate price level varies with skewness of the cross sectioanal distribution relative price changes.[4]

Further, Ball and Mankiw (1995) argue that variance of the distribution of shocks also influences the aggregate price level by amplifying the impact of skewness on inflation. They demonstrated that raising the variance of symmetrically distributed shocks leads to increase in density of both the tails equally. Therefore, price increases by some firms and reductions by others cancel out to zero and aggregate price level remains unchanged. However, in contrary to this, when the distribution of shocks is positively (negatively) skewed, the absolute increase in the right (left) tail is larger than the left (right) tail at higher level of variance. Thus for a given skewness, a higher variance tends to magnify the asymmetry in the tails and hence, changes the aggregate price level both in upward and downward direction depending on the size and sign of skewness. Therefore, the anticipation is that the effects

[4] For a detailed graphical description on this see Amano and Macklam (1997).

of skewness will be larger at the higher level of variance, but variance itself has no independent effect on inflation.[5]

Symmetric Shocks with Trend Inflation

Ball and Mankiw (1994) discuss the price adjustment of firms in presence of trend in inflation. As in previous setting, they again assume an economy with monopolistically competitive firms that pay costs to change prices. Firms adjust prices only if the deviation between the initial price and the desired price surpasses some threshold in either direction. They have shown that, under certain conditions, trend inflation introduces an asymmetry in price adjustment; in the sense that firms adjust prices upwards more quickly than downwards in response to shocks to their desired prices.

In presence of trend inflation, a firm hit with a negative shock to its desired price can either choose to pay the menu costs and change its price immediately or avoid paying menu costs and wait for inflation to reduce its relative price to the desired level. Thus, at higher inflation, firm's relative price will be eroded at a faster rate, and it is less likely that a firm will pay menu cost and change its price in response to a negative shock. In other words, a negative shock to its optimal price may not elicit a reaction because the firms' know that inflation will do much of the work of reducing its nominal price towards its desired price. Thus, the trend inflation tend to increase the range of inaction for negative shocks and reduces the zone in which firms pay the menu costs to adjust their prices downwards.

In contrary to this, when a firm faces a positive shock of the same size to its desired price, waiting will simply widen the gap between the actual relative price and its desired level as inflation is expected to continuously erode the actual/prevailing relative price over time. Under

[5] For other various combination of skewness and variance and the resultant outcomes from the model see, Pou and Dabus (2008).

these circumstances, a firm is therefore more likely to pay the menu costs and quickly raise its price to equilibrium level. This implies that positive trend inflation cause prices to adjust upwards more quickly than downwards and hence makes downwards adjustments stickier/rigid. Note that, it is the presence of positive trend inflation that generates the asymmetric price response.[6] Further, the anticipation is that the negative trend in inflation generates asymmetry in reverse direction; that is price adjust more quickly downwards than upwards. However, when expected inflation is zero, such asymmetry in the price adjustment is expected to disappear. Therefore, the firm's response to a particular shock depends on both the *sign* as well as *size* of the shock.

The implication of such asymmetries in price adjustment is that larger variability in shocks will tend to increase the aggregate price level even when the shocks across firms are symmetrically distributed (Ball and Mankiw, 1995; Amano and Macklem, 1997). This is based on the rationale that larger variance in shocks cause larger number of firms to adjust their prices and as most of these adjustments are in upward direction, the aggregate price level will rise. Hence, higher variance of shocks causes larger increase in the absolute size of the right side tail than the left tail, which in turn results in higher aggregate price level. The menu cost models anticipates that in presence of trend the inflation, variance has an independent positive effect on aggregate price level.

Some Alternative Explanations

Menu cost model of Ball and Mankiw (1994, 1995) have spawned an intensive debate among theoretical and empirical macro economists. On the theoretical front, Balke and Wynne (2000) challenged the menu cost explanation of Ball and Mankiw (1994) about the association between skewness of the distribution of relative price changes and inflation. Assuming a multi-sector flexible price general equilibrium model they

[6] Such asymmetry in price adjustment can also be generated by asymmetry in menu costs (Kuran, 1983).

argued that sectoral technology shocks can also generate relationship between relative price changes and aggregate inflation. They emphasized that a positive correlation between the skewness of relative price changes and the aggregate inflation rate is not a feature unique to menu cost models. The economic reasoning underlying their line of argument is built on the notion that in a flexible price model a positive sector-specific technology shock will lead to rise in the output of that sector and fall in relative price of output from that sector. Balke and Wynne (2000) argued that even in a flexible price model if sufficient number of industries are buffeted by sectoral shocks of the same sign and some sectors are affected more than others, such shock can also generate positive correlation between skewness and aggregate inflation. Further, Nath (2004) argued that changes in sector-specific factors such as technology shocks to certain sectors or changes in sectoral autonomous expenditures may change the demand and supply conditions across sectors in such a manner that they may cause changes in both relative prices and aggregate inflation.

On the other hand, Bryan and Cecchetti (1999) claim that the link between the skewness of the distribution of relative price changes and aggregate inflation found by researchers might be a statistical artifact. They argue that the positive association between skewness of the distribution of relative price changes and aggregate inflation rate observed in empirical literature arises due to small-sample bias. They computed the magnitude of such a potential bias using numerical simulations and concluded that the magnitude of such bias might account for the positive correlation between skewness of the distribution of relative price changes and aggregate inflation.

However, Ball and Mankiw (1999) argued that the small sample bias of the type observed by Bryan and Cecchetti (1999) could arise only in a model wherein a subset of distribution of observed relative price changes is drawn from an underlying true distribution of relative price changes. They argued that the measure of aggregate inflation is based on price changes across all the sectors of an economy and hence, by construction a small sample-bias cannot arise. Further, they criticized the Monte Carlo experiments of Briyan and Cecchtti (1999) for failing to capture the true nature of the cross sectional sampling involved in the construction of aggregate inflation and also emphasized that the design of such experiment is not derived from economic theory.

DATA AND METHODOLOGY

The monthly data on the commodity wise Wholesale Price Index (WPI) for the period from April 1993 to August 2010 has been used for empirical analysis. The advantage of using WPI data is that it is consistently available at highly disaggregated level and for longer period of time. The old measure of WPI comprises of 435 commodity prices under three different categories: (i) Primary articles; (ii) Fuel, Power, Light, and Lubricants; and (iii) Manufactured Products with weights 22.025, 14.226, and 63.749%, respectively.[7] Out of total 435 commodities, 87 fall under the category of primary articles, 17 under fuel-power and lubricants and the rest of 331 are under the category of manufactured products. The complete time series derived from a uniform definition of the each price indices covering the entire sample period were available on 419 commodities, which constitutes 96 percent of commodity prices used in the construction of WPI in India. The choice of the sample period is dictated by the availability of consistent time series on entire price indices. The data is collected from the website of Office of the Economic Advisor, Ministry of Commerce and Industry, Government of India.

[7] In September 2010, Government of India has enlarged the WPI basket which now includes 676 commodity prices.

Relationship Between Inflation and Skewness of Relative Price Changes

The various moments of the cross sectional distribution of relative price changes is computed as follows. Let the price of i^{th} commodity observed in period *t* be denoted as p_{it} . The rate of change in price of i^{th} commodity between time period *t* and *t-1* is denoted as π_{it} and can be measure as:

$$\pi_{it} = \ln(p_{it} / p_{it-1}) \tag{1}$$

The aggregate/average inflation rate (π_t) in period *t* can then be measured as the weighted average of price changes of individual commodities in time *t*, as follows:

$$\pi_t = \sum_{i=1}^{N} \omega_i \pi_{it} \tag{2}$$

where *N* denotes the number of commodities in the sample and ω_i represents the weight of i^{th} commodity. The standard deviation (σ_t) of cross-sectional distribution of price changes is measured as:

$$\sigma_t = \sqrt{\sum_{i=1}^{N} \omega_i \left(\pi_{it} - \pi_t\right)^2} \tag{3}$$

And the skewness of cross sectional distribution of relative price changes, depicted as S_t, is measured as:

$$S_t = \left[\sum_{i=1}^{N} \omega_i \left(\pi_{it} - \pi_t\right)^3\right] \times \sigma_t^{-3/2}. \tag{4}$$

Before examining the relationship between inflation and skewness some empirical issues needs to be addressed. First, since the data used is of monthly frequency, it needs be adjusted for seasonality. Second, as higher order moments of the cross sectional distribution of relative price changes are used, it is likely that the problem of multicollinearity may appear (Caraballo and Usabiaga, 2004). Finally, the time series properties of all the variables need to be examined. To address the issue of seasonality, the X-12 (ARMA) method is used to deseasonalize the data. To examine whether there is possibility of multicollinearity, we calculated the correlation coefficients between σ_t and S_t, which is found to be 0.13. Since the correlation coefficient is very small, it plausible to include both these variables jointly in one equation. To examine the time series properties of the various variables, conventional Augmented Dickey-Fuller and Phillip-Perron tests are used.

After addressing all the concerns raised above, the following specifications are estimated using simple Ordinary Least Squares method.

$$\pi_t = \alpha + \sum \gamma_k \pi_{t-k} + \beta S_t + \varepsilon_t \tag{5}$$

$$\pi_t = \alpha + \sum \gamma_k \pi_{t-k} + \rho \sigma_t + \varepsilon_t \tag{6}$$

$$\pi_t = \alpha + \sum \gamma_k \pi_{t-k} + \beta S_t + \rho \sigma_t + \varepsilon_t \tag{7}$$

where β and ρ are the coefficients that capture respectively the effect of skewness and variance on the inflation. Also ε_t is a disturbance term with zero mean and constant variance. β and ρ are expected to be statistically different from zero and with positive sign in each specification as predicted by Ball and Mankiw (1995).

As in Ball and Mankiw (1995), we also introduced an interaction variable (τ_t), defined as $\tau_t = S_t \times \sigma_t$, to capture the joint effect of variance and skewness on the aggregate inflation. For a distribution with skewness zero, τ_t takes value zero, but for other values of skewness τ_t is positively correlated with variance in absolute terms. In other words, the variance magnifies the value of τ_t. To examine the influence of the interaction variable on inflation the following specification are estimated.

$$\pi_t = \alpha + \sum \gamma_k \pi_{t-k} + \phi\tau_t + \varepsilon_t \tag{8}$$

$$\pi_t = \alpha + \sum \gamma_k \pi_{t-k} + \phi\tau_t + \beta S_t + \varepsilon_t \tag{9}$$

where the coefficient ϕ captures the joint influence of skewness and variance. Again, ϕ is expected to be statistically significantly different from zero with positive sign as predicted by the menu cost model.

Frequency and Size of Price Changes

Following Horvath (2011), the frequency of price changes and the duration for which same price prevails for a particular commodity is defined as follows,

$$x_{it} = \begin{Bmatrix} 1 & if\ \pi_{it} \neq 0 \\ 0 & if\ \pi_{it} = 0 \end{Bmatrix}$$

And the average frequency at which a particular firm changes price is measured as,

$$f_{it} = \frac{1}{T} \sum_{t=1}^{T} x_{it}$$

where T is the number of time periods. The average size of price increase of a particular commodity is given as,

$$s_{it}^{+} = \frac{1}{T}\sum_{t=1}^{T} D_{it}\left(\pi_{it}\right), \qquad where \quad D_{it} = \begin{Bmatrix} 1 & if\ \pi_{it} \succ 0 \\ 0 & if\ \pi_{it} \leq 0 \end{Bmatrix}$$

And similarly average size of price decreases or falls is measured as,

$$s_{it}^{-} = \frac{1}{T}\sum_{t=1}^{T} D_{it}\left(\pi_{it}\right), \qquad where \quad D_{it} = \begin{Bmatrix} 1 & if\ \pi_{it} \prec 0 \\ 0 & if\ \pi_{it} \geq 0 \end{Bmatrix}$$

In such framework, the size of price changes is calculated as the percentage increase (decrease) in the price of a particular item during the period from *t-1* to *t*.

EMPIRICAL RESULTS

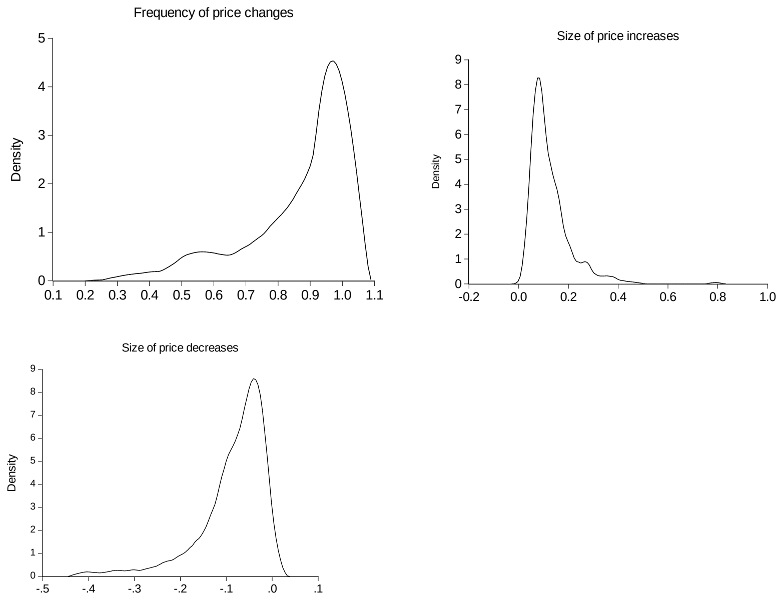
In the following section, we examine some basic properties of distribution of price changes and also analyze size and frequency of price changes across firms. Subsequently, the empirical results on the relationship between inflation and skewness of the distribution of relative price changes are presented. Since skewness is assumed to capture effects of nominal rigidity, the time interval between which price changes are measured is likely to be important as it may influence the results. Therefore, we have used skewness and variance constructed from both price changes measured as monthly log-difference and annual price changes measured as twelve month log-difference.

Frequency and Size of Price Changes

To begin with, we estimated the size and frequency of price changes across various prices. It is commonly believed that firms do not change prices quite often at higher degree of price rigidity (Mankiw, 1985). Also, the size of price change across firms is likely to be larger than otherwise as the new optimal price in each period is farther from the prevailing one (Mankiw, 1985). To examine this, in the Figure 1, the Kernel density functions of frequency and size of price changes is presented. Kernel density estimation is a non-parametric approach of estimating the probability density function of a random variable, where y-axis measures density values and x-axis gives the points at which these density values are evaluated.

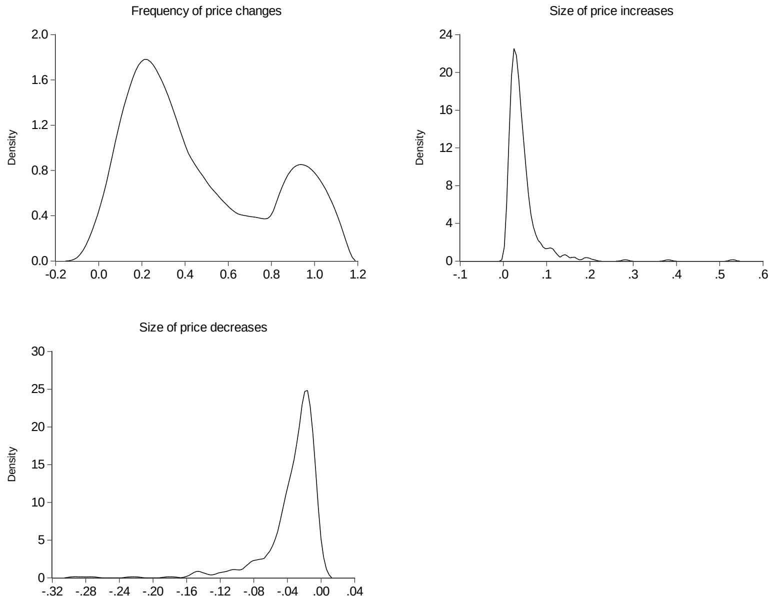
Figure 1: Frequency and Size of Price Changes

Panel-A (annual price changes)



Source: Authors' estimation.

Panel-B (monthly price changes)



Source: Authors' estimation.

The first graph presented in panel-B of Figure 1 indicates that a typical price does not change even once in a particular month. This reflects a higher degree of rigidity in price adjustments in an economy. However, there seems to be certain prices, mostly belonging to primary articles, which do change once in a month.

The second graph in Panel B of the Figure provides Kernel density for the size of price increase. Conditional on frequency of price change, the result suggests that the magnitude of the price increase is around 0.5 percent. Similarly, the Kernal density given in the third graph of the Panel B suggests that the magnitude of price decrease is closer to zero. These results suggest that average size of price increase is greater than average size of price decrease.

Similar results were found when annual price changes are considered. The Kernel density presented in Panel-A of the Figure 1 suggests that most of the firms change price once in a year. Here also, the average size of price increases is greater than the size of price decreases. The lower frequency of changes in prices indicates that there exists both real and nominal rigidities in the economy.

Descriptive Statistics

Before proceeding to more systematic empirical analysis, this section provides descriptive statistics on the time series of various variables used. In the Table 1, we have presented the descriptive statistics for the variables constructed from both annual as well as monthly price changes. The estimates given in the first row of the Table show that the average inflation rate observed during the period is found to be around 5%. The maximum inflation rate observed is 15% and the minimum is 0.06%. This indicates a large variation in the rate of inflation over the sample period. Compared to this, the mean of the time series of inflation rate measured from monthly price changes is 0.004 and its standard is deviation 0.026 as given in the row five of the Table.

The cross sectional distribution of price changes for most of periods turns out to be positively skewed. In fact, the distribution of price changes is found to positively skewed for 137 out of total 197 periods during the sample period.[8] This indicates the tendency of chronic positive skewness in the distribution of price changes. Number of empirical studies such as Buck and Gahlen (1983) and Mizon et al. (1989) have provided evidence in favour of such chronic positive skewness in the distribution of price changes for many developed countries. Theoretically, this phenomenon is attributed to asymmetries in the price adjustments due to downward rigidity in prices or differential adjustment lags.

[8] The null of normality is rejected in favour of positive skewness for most of the periods. The results from the normality tests are not presented.

Table 1: Descriptive Statistics

Variables	Mean	Median	Standard deviation	Maximum	Minimum	Skewness
	Annual price changes					
π_t	0.054	0.05	0.028	0.15	0.006	1.11
S_t	0.789	0.65	1.319	6.15	-1.474	1.33
σ_t	0.016	0.01	0.004	0.03	0.010	0.95
τ_t	0.014	0.01	0.026	0.13	-0.037	1.21
	Monthly price changes					
π_t	0.004	0.003	0.006	0.065	-0.013	4.02
S_t	0.482	0.985	4.297	15.09	-20.93	-0.72
σ_t	0.036	0.033	0.011	0.120	0.018	2.52
τ_t	0.017	0.033	0.188	1.038	-0.537	3.12

Source: Authors' estimation.

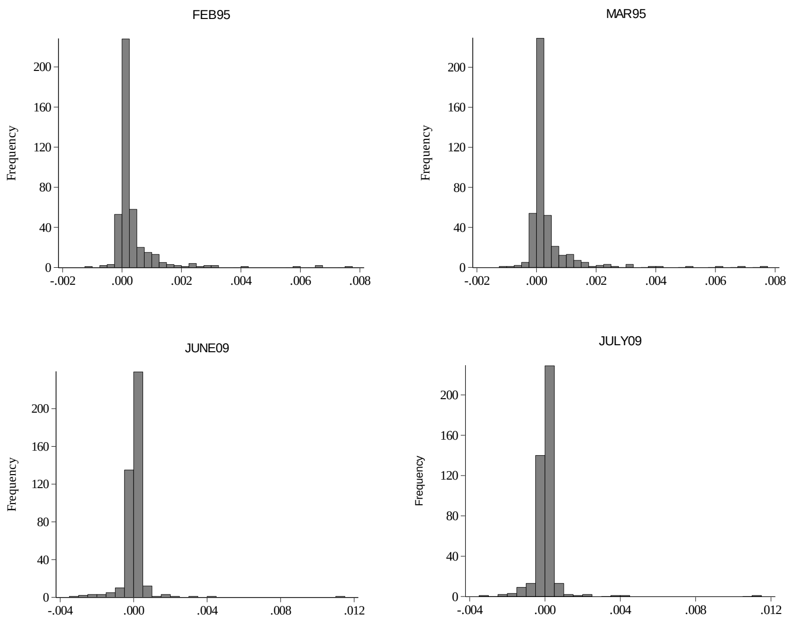
The distribution of Relative Price Changes

To provide an initial idea about variations in shape of distribution of relative price changes, we have plotted histograms of cross sectional commodity price changes for some periods (both monthly and annual changes) in Figure 2.[9] In Panel-A of the Figure, the distribution of annual price changes is presented. The first two histograms correspond to the periods with higher inflation rate and the next two correspond to the periods with relatively lower inflation rate. It is evident from the Figure that there seems to be considerable variation in distribution of price changes. It can be clearly observed from the histograms that during the periods of higher inflation rate - February 1995 and March 1995 - the distribution is skewed sharply to the right. Whereas, during the periods with lower rate of inflation – June 2009 and July 2009 - the distribution is

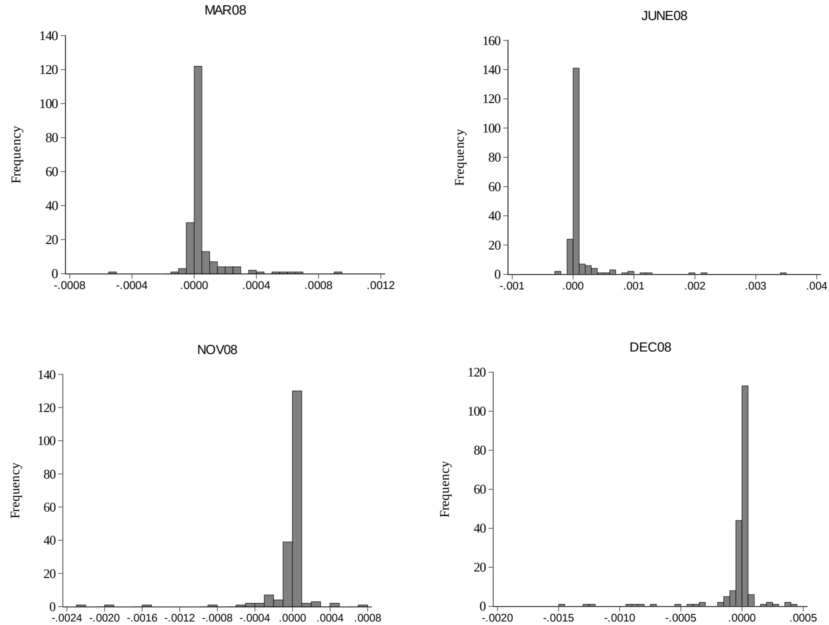
[9] Weighted commodity price changes are used for analysis.

sharply skewed to the left. Thus suggesting that for the periods with higher positive skewness in the distribution of price changes, the aggregate inflation appears to be higher. In fact, the initial two periods correspond to periods during which Indian economy has undergone huge policy shifts in the form of comprehensive economic reforms.

Figure 2: Distribution of Relative Prices Changes
Panel-A (Annual price changes)



Panel-B (monthly price changes)

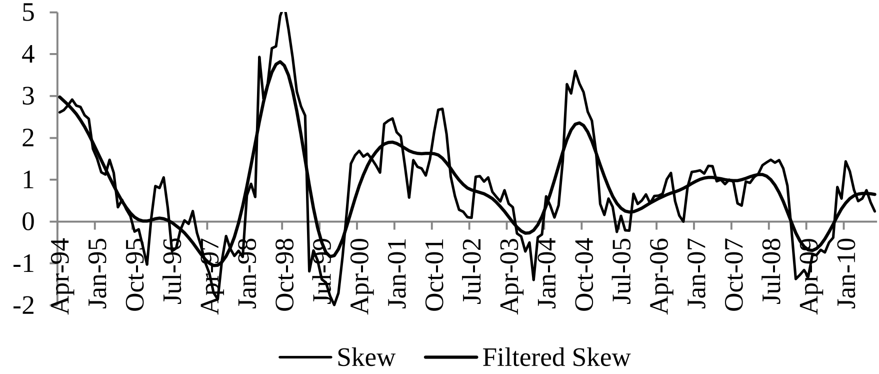


Source: Authors' estimation.

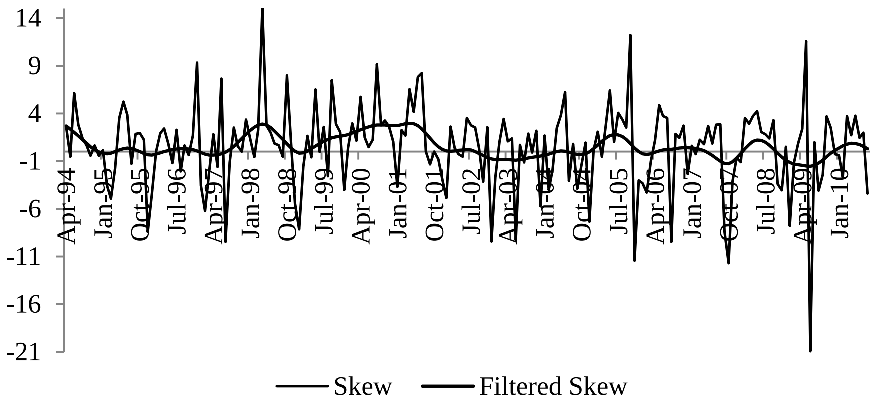
In Panel-B of the Figure 2, we present histograms of cross sectional distributions of price changes which are measured as monthly log-differences. As above, the first two histograms correspond to higher inflationary periods whereas the latter two corresponds to periods with lower inflation rate. Here also, a period with higher rate of inflation corresponds to the period with sharply positively skewed distribution of price changes and the periods with lower inflation correspond to the periods with negatively skewed distribution. Therefore, the same conclusion holds for the monthly price changes as well.

To examine the dynamics of distribution of relative price changes, following Asserossion (2002), we calculated the trend component of both skewness and standard deviation of distribution of price changes by using Hordick-Prescott filter. The trend/persistent component of skewness is plotted with its actual series for both annual and monthly price changes in Panel A and B of the Figure 3, respectively. The graph given in Panel A of the Figure depicts that the distribution of annual price changes is positively skewed for most of the time periods even in the long-run as its trend/persistent trend component for most of the periods turns out to be positive. In fact, for 147 out of total 197 months, the cross sectional distribution turns out to be positively skewed. The average value of coefficient of skewness is found to be 0.82. In consistent with findings from the Table 1, this indicates the chronic tendency of positive skewness in the distribution of price changes. This chronic tendency towards positive skewness is consistent with the theoretical view that in presence of trend in inflation price increases occur more quickly than price decreases as inflation continuously erodes the relative price of a particular firm (Ball and Mankiw, 1995). However, this result is in contrary to view that the skewness observed in distribution of relative price changes is sourced through the nominal rigidities, which is a short-run phenomenon and hence is expected to disappear in the long-run. Aucremanne et al. (2002) have found similar evidence of chronic positive skewness in the distribution of relative price changes using Australian data.

Figure 3: Actual and Filtered Skewness of Relative Prices Changes
Panel-A (annual price changes)



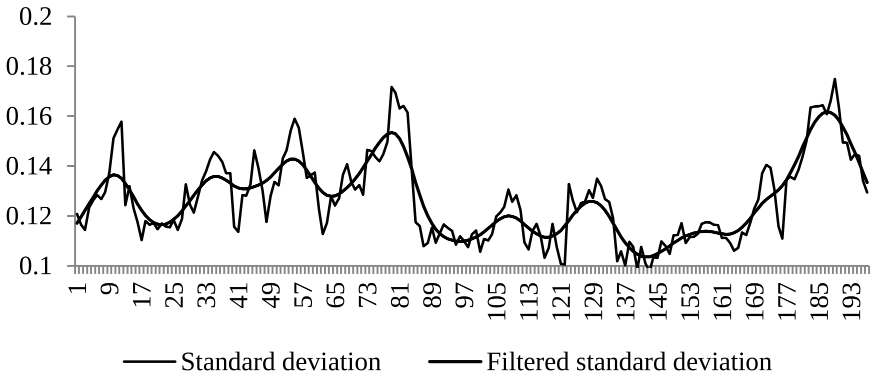
Panel-B (monthly price changes)



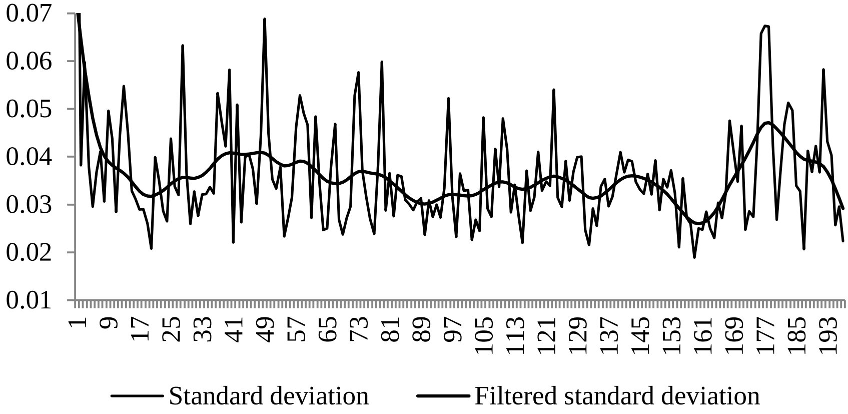
Source: Authors' estimation.

In the Figure 4, we have plotted the standard deviation of cross sectional distribution of relative price changes and its trend component over time. In Panel-A of the Figure the time series on actual and the trend standard deviation constructed from annual price changes are plotted together. Similarly in Panel-B both the trend and the actual series of standard deviation constructed from monthly price changes is plotted. The standard deviation constructed from monthly price changes seem to be stable over time except for the recent period. During recent period the standard deviation of cross sectional distribution of price changes rises; indicating large variation in the individual commodity price changes. As a consequence, the influence of skewness on rate of inflation will be strengthened as higher standard deviation magnifies the impact of skewness on the inflation.

Figure 4: Actual and Filtered Standard Deviation of Relative Prices Changes
Panel-A (annual price changes)



Panel-B (monthly price changes)



Source: Authors' estimation.

Unit Root Tests

Before proceeding to the regression analysis, we examined the time series properties of inflation and other variables by using Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests. The results obtained from these unit root tests are presented in Table 2 for both the annual and monthly price changes. When variables constructed from annual price changes are considered, the results suggest that the null hypothesis that the series has unit root is rejected at conventional level of significance for all variables. This confirms that all the variables constructed from annual price changes are stationary and hence follow *I(0)* process.

Similarly, when the variables constructed from the monthly price changes are considered the test statistics from both the tests, ADF and PP, indicate that all the variables are stationary and hence follow I(0) process.

Table 2: Unit Root Test

Variables	ADF Test	PP Test
	Annual price changes	
π_t	-2.71 (0.04)	-2.80 (0.02)
S_t	-2.96 (0.00)	-3.43 (0.00)
σ_t	-3.66 (0.00)	-3.45 (0.01)
τ_t	-4.33 (0.00)	-3.46 (0.00)
	Monthly price changes	
π_t	-5.61 (0.00)	-11.2 (0.00)
S_t	-12.9 (0.00)	-12.8 (0.00)
σ_t	-12.7 (0.00)	-12.7 (0.00)
τ_t	-13.8 (0.00)	-13.8 (0.00)

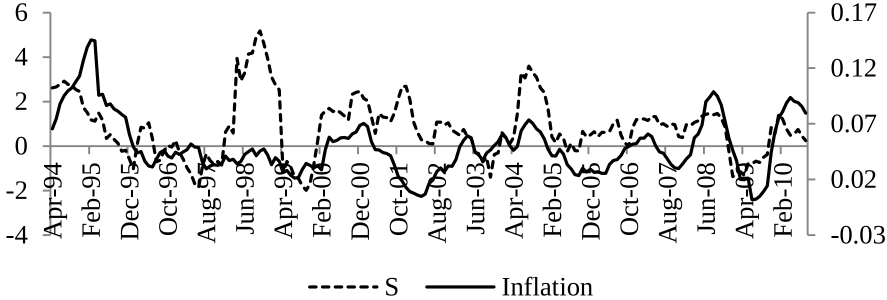
Note: In the parentheses are p-values
Source: Authors' estimation.

Inflation and the Moments of Distribution of Relative Price Changes

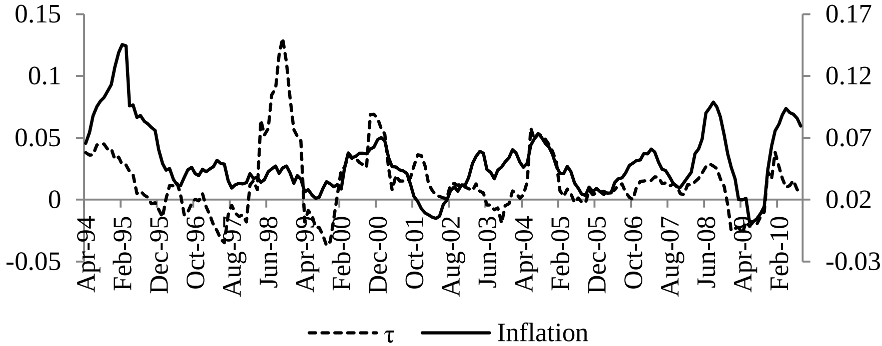
To visualize the relationship between inflation and various moments of distribution of relative price changes, we plotted inflation with skewness (S_t) and subsequently, with the interaction variable (τ) obtained from annual price changes in Panel A and B of the Figure 5, respectively. Also, the variables constructed from monthly price changes are plotted in Panel A and B of Figure 6. This preliminary graphical analysis visualizes the influence of skewness and variance on the rate of inflation.

Figure 5: Aggregate Inflation, Skewness and Interaction – Annual Price Changes

Panel-A



Panel-B

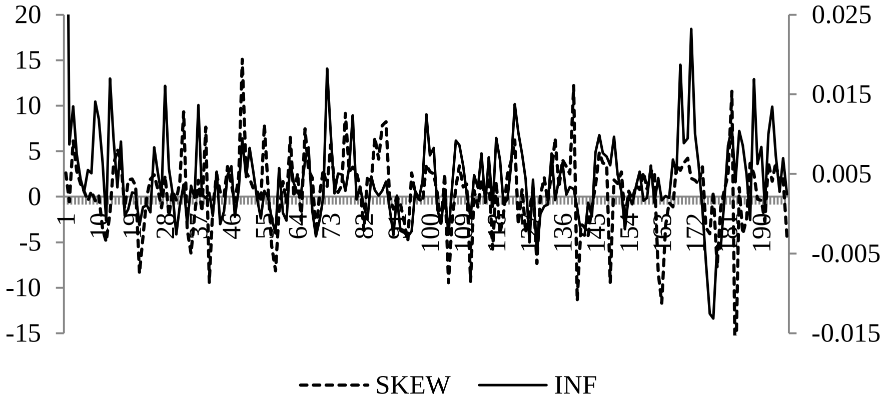


Source: Authors' estimation.

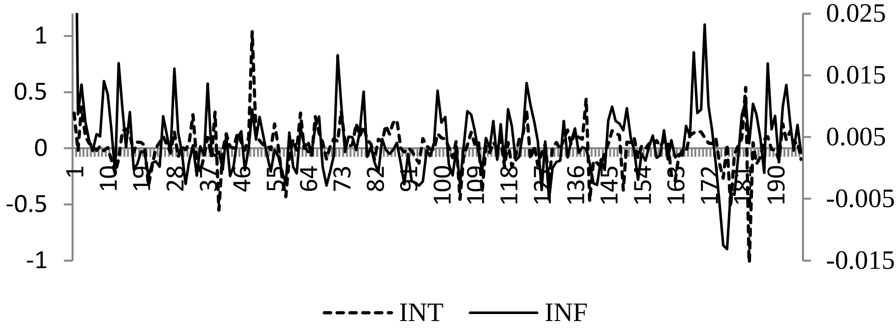
Both the graphs in Panel A and B of the Figure 5 display that the basic empirical prediction of the Ball and Mankiw model is apparent in the data. The skewness (S_t) of the cross sectional distribution of relative-price changes varies substantially over time and it closely varies with the inflation rate. The figure depicts that the periods of substantial negative skewness tend to be periods of lower inflation whereas the periods of significant positive skewness tend to be periods of high inflation. This association between inflation and skewness is much visible in Panel-B wherein inflation is plotted with interaction variable (τ). This implies that the variance is strengthening the influence of the skewness on the inflation rate. These results are more clear from Panel A and B of Figure 6 where the variables constructed from monthly price changes are considered. As in Figure 5, inflation closely follows the trajectory of both the skewness and its variant - interaction variable. The periods with higher value of skewness correspond to periods of higher rate of inflation and vice versa. Here also, the interaction variable is closely commoving with the aggregate inflation rate over period of time.

Figure 6: Aggregate Inflation, Skewness and Interaction– Monthly Price Changes

Panel-A



Panel-B



Source: Authors' estimation.

The sharp rise in aggregate inflation during the initial period reflects both severe production shortfall of primary goods and sharp rise in M3 money growth experienced during that period. Subsequently, due to the Reserve Bank of India's monetary contractions and the better management on supply side there was a drastic fall in the inflation rate.

Next, we turn to more systematic investigations to test the basic predictions of menu cost models about the inflationary effects of skewness and variance of cross sectional distribution of relative price changes. As in Ball and Mankiw (1995), in all specifications the left hand side variable is inflation and on the right side of each equation is skewness and variance of distribution of relative price changes, as given in the section 3. All the specifications were estimated using a simple Ordinary Least Squares (OLS) method. As mentioned earlier that the time interval between which price changes is measured is likely to influence the results. Therefore, the variables constructed from both annual and monthly price changes were used to examine the relationship. In the Table 3, we present the results obtained from the model wherein variables constructed from the annual price are used. Subsequently, the Table 4 provides the results from the model where the variables constructed from monthly price changes are used.

Table 3: Results from Annual Price Changes

Variables/model	(1)	(2)	(3)	(4)
π_{t-1}	1.346 (0.00)	1.336 (0.00)	1.315 (0.00)	1.362 (0.00)
π_{t-2}	-0.417 (0.00)	-0.408 (0.00)	-0.3944 (0.00)	- 0.3875 (0.00)
λ_t	0.081 (0.04)	-	0.068 (0.05)	-
σ_t	-	0.028 (0.00)	0.027 (0.00)	-
τ_t	-	-	-	0.550 (0.04)
R^2	0.93	0.93	0.93	0.92
DW	2.12	2.09	2.07	2.06

Note: In the parentheses are p-values.
Source: Authors' estimation.

In Column (1) of the Table 3, the results for a benchmark regression wherein a constant, lagged inflation and skewness are used as regressors are presented. Column (2) provides the results obtained from a regression wherein a constant, the lagged aggregate inflation rate, and the variance are used. Column (3) gives results from a specification where both the variance and the skewness in addition to lagged inflation are used as regressors. Finally, Column (4) provides the results for the regression wherein interaction term is also included in the bench mark specification.

It is evident from the results presented in Table 3 that coefficient associated with the lagged inflation is highly significant and its value appears to be closer to one in all the specifications. This indicates higher degree of persistence in the aggregate inflation. Secondly, the coefficient associated with skewness is found to be highly significant with appropriate sign in all the specifications wherever it is included. The results indicate that the null hypothesis that the coefficient associated with skewness is zero is rejected in all the specifications. Further, the coefficient associated with variance also turns out to be significant.[10] These regressions reveal that the skewness of the distribution of relative price changes exert a significantly positive effect on the inflation. [11]

The interaction variable which captures joint effect of skewness and variance is also highly significant with a proper sign; thus implying an indirect amplifying effect from the variance to the aggregate inflation.[12] These results suggest that in the presence of skewness higher (lower) variance will increase (decrease) the inflation. These results are consistent with the predictions of menu cost models and many empirical findings (e.g., Amano and Macklem, 1997; Assarsson, 2004; Pou and Debus, 200; and Caraballo and Dabus, 2008). These empirical results provide strong evidence on the view that skewness of the distribution of relative price changes and aggregate inflation are positively related, as predicted by the Ball and Mankiw (1995).

Table 4: Results from Monthly Price Changes

Variables	(1)	(2)	(3)	(4)
C	0.002 (0.00)	-	-	0.002 (0.00)
π_{t-1}	0.248 (0.00)	0.258 (0.00)	0.238 (0.00)	0.242 (0.00)
λ_t	0.040 (0.00)	-	0.039 (0.00)	-
σ_t	-	0.084 (0.00)	0.082 (0.00)	-
τ_t	-	-	-	0.948 (0.00)
R^2	0.23	0.18	0.30	0.25
DW	1.81	1.70	1.73	1.80

Note: In the parentheses are p-values.

Source: Authors' estimation.

[10] Same conclusion can be drawn from results when unweighted price changes are used (not presented here). However, in the unweighted regressions, the coefficient associated with the variance is found to be in significant. This result is in consistent with Ball and Mankiw (1995).

[11] Similar results are found by Mackalam (1996), Beng Assersion (2000).

[12] By indirect effect we mean the impact through skewness.

The results obtained from regressions wherein variables constructed from monthly price changes are used provide more clear idea about this relationship. The results from such regression models are presented in the Table 4. The results suggest that the null hypothesis that the coefficient associated with skewness or its variant is zero is rejected at conventional level of significance in each specification. It can be clearly seen from the sixth row of the Table 1.4 that R^2 improves drastically when skewness or its variant is included in any specification. Over all, these results are consistent with the results obtained from annual price changes. In consistent with the results presented in Table 1.3, these results provide strong evidence in favour of the view that skewness of the distribution of relative price changes positively influence the aggregate inflation.

Alternative Measures of Asymmetry

In this section, we test for significance of alternative measures of skewness. According to menu cost model of Ball and Mankiw (1995), it is the relative size of the tails of distribution of price changes which determines the fluctuations in the inflation. Hence, it is more accurate to define a single variable which can capture the joint effect of both skewness and variance on inflation. To this end, we follow Ball and Mankiw (1995) and define a variable μ_t^X, for a certain cut off X, as

$$\mu_t^X = \sum_{i=1}^{l} \omega_i (\pi_{it} - \pi_i) D_i^- + \sum_{i=1}^{u} \omega_i (\pi_{it} - \pi_i) D_i^+ .$$

This gives us a measure of net mass in the extreme tails of distribution. Where, D_i^+ and D_i^- are dummy variables and X is some arbitrarily chosen cut off.[13] The former term takes the value one when i^{th} industry's relative price change falls in the upper X per cent of the

[13] Choosing cut off X is an empirical question and the optimal cut off might vary across economies. Ball and Mankiw (1995) used a range of values ranging from 15% to 50%.

distribution and zero otherwise, and the latter term is one when i^{th} industry's relative price change falls in the lower X per cent of the distribution and zero otherwise. Thus first part of the μ_t^X measures the mass in lower tail of the distribution which is measured as the summation of relative price changes lower than X percent. Similarly, the second part of the variable measures the mass in the upper tail which is estimated as the summation of relative price changes greater than X percent. μ_t^X is zero for a symmetric distribution, positive when the density of right tail is greater than the left tail and is negative in the reveres case. Further, for a given value of skewness, μ_t^X rises in absolute value since higher the variance larger the density of tails.

The problem with μ_t^X is that in its construction similar weights are assigned to the price changes irrespective of how extreme a particular relative price change lies in the tails of the distribution. In fact, full weight is given to price changes which are above (or below) the cut off X, irrespective of their size and zero weight to the remaining price changes. However, theoretically the price change in the extreme tail of the distribution, in either side, is expected to influence inflation more strongly than the price changes lying closer. In this context, Ball and Mankiw (1995) suggest a variant of μ_t^X wherein weights increase linearly with the size of price changes, as given below,

$$\theta_t = \sum_{i=1}^{n} \omega_i \left| \pi_{it} - \pi_t \right| (\pi_{it} - \pi_t)$$

Here, θ_t is defined as the weighted average of product of each relative price change and its own absolute value. θ_t is zero for a symmetric distribution and positive for rightly skewed distribution. Also, its value is magnified at higher levels of variance.

To examine the influence of the such asymmetry measures, we replaced the skewness (*S*) used in the previous section by μ_t^X and θ_t, alternatively. In the Table 5, we have presented the results obtained from the regressions wherein the asymmetry measures (μ_t^X and θ_t) constructed from both annual and monthly price changes are used. The results presented in column (1) and (2) suggest that the null hypothesis that the coefficient associated with μ_t^X is equal to zero is rejected at 1% level of significance.[14] Similarly, the results presented in column (3) suggest the coefficient associated with θ_t is statistically different from zero, hence, indicating that the net mass in the tails of distribution of price changes is an important determinant of fluctuation in aggregate inflation. The same conclusion can be drawn from the regression wherein the variables constructed from monthly price changes are used, as given in column (4), (5) and (6). Here also, it can be easily seen that R^2 improves significantly with the inclusion of any variant of skewness measure.

[14] Here, we have presented the results for 10 and 20% cut off. The change in cut off does not alter the results significantly.

Table 5: Alternative Asymmetry Measures

Variables	(1)	(2)	(3)	(4)	(5)	(6)
	Annual Price Changes			**Monthly Price Changes**		
C	0.002	0.002	0.0030	0.001	0.002	0.002
	(0.02)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
π_{t-1}	1.283	1.202	1.264	0.164	0.207	0.161
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
π_{t-2}	-0.381	-0.301	-0.356	-	-	-
	(0.00)	(0.00)	(0.00)			
μ_t^{10}	0.312	-	-	1.445	-	-
	(0.00)			(0.00)		
μ_t^{25}	-	0.370	-	-	1.86	-
		(0.00)			(0.00)	
θ_t	-	-	0.598	-	-	4.77
			(0.00)			(0.00)
R^2	0.93	0.93	0.93	0.66	0.33	0.56
D W	2.02	2.18	2.01	1.70	1.85	1.80

Note: In parenthesis are p-values.

Source: Authors' estimation.

In sum, the empirical results suggest that there is a significant positive relationship between inflation and skewness of cross sectional distribution of relative price changes. The variance is found to have magnifying effect in the sense that it strengthens the impact of skewness on the rate of inflation. These results provide strong evidence in favour of the view that rigidities in price adjustments influence the dynamics of inflation at least in the short-run as argued by Ball and Mankiw (1994).

CONCLUSION

This study examines the relationship between skewness of the cross sectional distribution of relative price changes and aggregate inflation by using commodity wise Wholesale Price Index data for the period from April 1993 to August 2010. Simple Ordinary Least Squares technique is used to estimate the model. The empirical results provide strong evidence in favour of Ball and Mankiw (1995) argument that the skewness of cross sectional distribution of relative price changes explains a significant proportion of short-run fluctuations in aggregate inflation.

The empirical results provide the evidence in favour of the view that in presence of menu costs firms change price only in response to large shocks to their desired prices and prefer inaction in response to small shocks. Further variance of cross sectional distribution of relative price changes is also found to have positive influence on inflation. The results do not change when other alternative measures of asymmetry are used. Moreover, the results indicate that there seems to be a tendency of chronic positive skewness in the cross sectional distribution of relative price changes. More importantly, the empirical results suggest that most of the firms change price once in a year and the average size of price increase is greater than the size of price decrease implying downward rigidity in the prices of various commodities.

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