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# Inflation and Inflation-Uncertainty in India:
# The Policy Implications of the Relationship

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**Abstract**.

Inflation and its related uncertainty can impose costs on real economic output in any economy. This paper analyzes the relationship between inflation and inflation uncertainty in India. Initial estimates show the inflation rate to be a stationary process. The maximum likelihood estimates from the GARCH model reveal strong support for the presence of a positive relationship between the level of inflation and its uncertainty. The Granger causality results indicate a feedback between inflation and uncertainty. With Granger causality running both ways, the Friedman-Ball and Cukierman-Meltzer hypotheses hold simultaneously in India. It provides strong support to the notion of an opportunistic central bank in India.

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## I.        Introduction

One of the most remarkable macroeconomic events of the past two decades has been the significant decline in inflation in both the developed and emerging market economies. The behavior of inflation in India broadly exhibits such a pattern. For much of the 1970s and 1980s, India experienced repeated episodes of high and variable inflation, while there has been a sharp decline in average inflation since the 1990s (Figure 1). Can this progress on inflation be sustained, or is the current improvement only a temporary relief?

Inflation and its related uncertainty can impose costs on real economic output (Friedman (1977)). For the emerging markets, these costs may be higher than those in developed economies as inflation is still higher than desired in many of these markets. In particular, the population in the lower income strata may find it difficult to hedge against the costs of rising prices and inflation when combined with other distortions such as misaligned nominal exchange rates (Miles and Schreyer, 2009).

In order to minimize the adverse economic consequences and welfare costs of increases in the inflation rate, policymakers need a clear understanding of the major channels through which inflation may affect the real economy. One such channel comes from the effects that higher inflation has on inflation uncertainty. Theoretically, this arises from the public's perception of erratic policy responses by the monetary authority to price level changes (Ball, 1992; Valdovinos and Gerling, 2011). It reduces the efficiency of market prices as a coordinator of economic activity (Friedman, 1977) and negatively affects investment (Caballero, 1991). As shown by a large literature, these effects ultimately lead to a growth-dampening resource misallocation, even where inflation is low (See Karanasos and Kim (2005) for a survey of the early empirical literature on the real impact of inflation uncertainty).

 Newer evidence comes from, e.g., Chang and He (2010), Conrad and Karanasos (2008), and Grier et al. (2004) on the US; Fountas and Karanasos (2007) on the G7; Apergis (2005) on OECD countries; Wilson (2006) on Japan; Samimi and Shahryar (2009) on Iran; Grier and Grier (2006) on Mexico and Valdovinos and Gerling (2011) on the West African Economic and Monetary Union. In general,

the evidence is mixed. Grier *et al* (2004) and Karanasos *et al* (2004) employ US data and find evidence for a negative and positive effect of inflation uncertainty on inflation, respectively.

This paper intends to extend the empirical literature by analyzing the relationship between inflation and inflation uncertainty in India over the last five decades. The results will have important implications for policy makers in India as it will provide insights into how well discretionary policies can be fitted with the stylized facts of the economy. An analysis of the various characteristics of inflation would provide an important benchmark for economic agents in formulating their expectations for the future periods. This issue is particularly important for India given the surge in inflation since 2008. India now has the highest inflation of any major emerging market (exceeding 9%) and has struggled to bring it under control over the last two years. In the absence of tough fiscal actions, the Reserve Bank of India has responded by raising benchmark lending rates a number of times since March 2010, making it the most aggressive among the monetary authorities in the Group of 20 nations.

Following recent empirical studies, we first derive a measure of inflation uncertainty from a generalized autoregressive conditional heteroscedasticity (GARCH) model of inflation (accounting also for lagged and seasonal effects) and study the nexus between inflation and inflation uncertainty in a bivariate VAR context. The direction of causality between inflation and inflation uncertainty is then identified using Granger causality.

The paper is organized as follows. Section II reviews the existing literature while Section III discusses the inflationary trend in India. Section IV provides the data sources and presents the estimation results. The paper concludes with a summary and policy implications of the results in Section V.

## II.    Literature Review

The linkages between actual inflation and inflation uncertainty have been extensively analyzed in the literature. There are two conflicting views on the nexus between inflation and inflation uncertainty. In explaining the real effect of inflation, Friedman (1977) put forward a two-part argument. First, he suggested that an increase in inflation may lead to an erratic policy response by the monetary authorities which, in turn, would mean more uncertainty about the future rate of

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inflation. Second, he predicted that inflation uncertainty would have a negative effect on output. Ball (1992) provided a formal derivation of Friedman's hypothesis that higher inflation causes more inflation uncertainty.

Cukierman and Meltzer (1986) and Holland (1995) analyzed the causal effect of inflation uncertainty on inflation. Cukierman and Meltzer (1986) showed that, by providing an incentive for the monetary authority to create an inflation surprise in order to stimulate output growth, an increase in uncertainty about money growth and inflation will increase the optimal average inflation rate. In other words, a positive causal effect of inflation uncertainty on inflation is evidence of an 'opportunistic' central bank (Thornton 2007a). On the other hand, Holland (1995) showed that as inflation uncertainty increases due to increasing inflation, the monetary authority responds by lowering the money supply growth, in order to eliminate inflation uncertainty and the related negative welfare effect. Thus, a negative causal effect of inflation uncertainty on inflation is evidence of a 'stabilizing' central bank (Conrad and Karanasos, 2005; Thornton, 2007a). It is also possible that more inflation can lead to a lower level of inflation uncertainty (Conrad and Karanasos, 2005). Do any of these hypotheses hold for India?

The causal impact of inflation uncertainty on inflation has been empirically analyzed using the GARCH approach, among others, in Baillie *et al* (1996), Grier and Perry (1998, 2000) and Hwang (2001). In general, the evidence is mixed. Baillie *et al* (1996) find evidence supporting the Cukierman-Meltzer hypothesis for the UK and other high-inflation countries, while Grier and Perry (1998) in their G7 study find evidence in favor of the Cukierman-Meltzer hypothesis for some countries and in favor of the Holland hypothesis for others. Grier and Perry (2000) find a negative effect of inflation uncertainty on inflation in the US while Karanasos *et al* (2004) report a positive effect in the US.

While Davis and Kanago (2000) survey the early evidence on the impact of inflation on inflation uncertainty, for more recent studies on advanced countries, see, e.g., Caporale, Onorante, and Paesani (2009) or Fountas, Ioannidis, and Karanasos (2004) on the euro area; Cogley, Primiceri, and Sargent (2010), William and Vijverberg (2009), or Benati and Surico (2008) on the US; Conrad and Karanasos (2005) on the US, the UK, and Japan; Binetti and Martel (2005) on Canada; and Berument and Dincer (2005) or Bhar and Hamori (2004) on G7 countries.

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A number of studies have studied the relationship in the emerging market countries, e.g., Thornton (2007a) and Daal *et al* (2005) on emerging markets; Keskek and Orhan (2008) on Turkey; Thornton (2007b) on Argentina; Gomes (2007) on Brazil; Payne (2008) on Caribbean countries; Rizvi, Abbas, and Naqvi (2008) on Pakistan; Entezarkheir (2006) on Iran; or Thornton (2006) on South Africa. The results in these studies are also mixed.

Thornton (2006), using a GARCH model, reported a positive and significant relationship between the level and variability of monthly uncertainty in a number of emerging markets including India during 1957-2005 with causation running from inflation to uncertainty about future inflation. To the extent that inflation uncertainty has negative output effects, Thornton argued for the central bank to focus on price stability as one of the prime objectives of monetary policy. Daal *et al* (2005) studied the relationship in a number of developed and developing countries including India. For India, they found support for the Friedman-Ball and Holland hypothesis (negative relationship between inflation and inflation uncertainty). Rizvi *et al* (2009) found bi-directional causality between inflation and uncertainty in a number of Asian countries including India.

### III.    Inflationary Trend in India

Following the global financial crisis in 2008-9, India has experienced the highest inflation of any major emerging markets - in 2010 it was in double digits. Originally triggered by high food prices, inflation has in 2010 and 2011 become more generalized across the economy. Rising wages and costs of service inputs are apparently being passed on by producers along the entire supply chain. The inflation bears the symptoms of structural, rather than cyclical, in an economy characterized by supply constraints, skilled labor shortages and high expectations among its population. The Reserve Bank of India has responded by raising benchmark lending rates numerous times. But inflation has defied the central bank and government's predictions of softening, instead finding impetus in rising food, energy and manufactured product prices. In fact, there are indications that inflation has shifted prices higher to a 'new normal' in a country that has traditionally had a low cost base.

In recent years, issues relating to inflation and its measurement in India has received a great deal of attention, reflecting some new realities (Reddy, 1999). First, following the start of the financial liberalization process in 1991 and the subsequent dismantling of most administered interest rates, the link between inflation, interest rate and forward exchange premia are closely observed by financial intermediaries. Second, in a more globalized economy with a view to maintain

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competitiveness of domestic economy, market participants carefully track inflation to anticipate and assess monetary policy changes.

In general, compared to other emerging markets, India's inflation performance would be considered as satisfactory (Table 1 and Figure 1). Since the early 1950s, inflation as measured by the Wholesale Price Index (WPI), on an average basis, was above 15% in only five out of more than 50 years. In thirty-six out of fifty years, inflation was in single digit. On most occasions, high inflation was due to supply shocks -food or oil shocks (Table 2). The inflation rate accelerated steadily from an annual average of 1.9% during the 1950s to 6.2% during the 1960s and further to 10.3% in the 1970s before easing to 7.4% in the 1980s (Table 1 and Reddy, 2007). However, the inflation rate dropped from 7.8% in the 1990s to 5.4% during 2000-2010 (Table 1).

Thus India recorded relatively satisfactory levels of inflation during our sample period, with the average inflation rate working out to be around 6.4%. The inflation rate has been far less volatile than in most emerging markets with standard deviation at 6.8 (see Table 3). Over the last five decades, at least 9 episodes of double digit inflations can be identified in Figure 1 (see also Table 2). Of these nine episodes, double digit inflation lasting more than a year happened during five different periods – the most prolonged being the 30 months period during October 1972 to March 1975. These high episodes of inflation were caused mostly by exogenous shocks, such as, oil price hike, Gulf crisis, wars, etc. and domestic supply shocks such as adverse monsoon conditions (Reddy, 1999). Mohanty (2010) examined these high episodes of inflation and argued that volatility as well as incidence and duration of double digit inflation has reduced over time and inflation rates have been on a downward trend in India in recent decades.

The Wholesale Price Index (WPI) is the main measure of the inflation rate in India and is considered as the headline inflation rate. The WPI is available for all commodities' and for major groups, sub-groups and individual commodities. The basic advantage of this measure of inflation is its availability in high frequency (on a weekly basis with a two week lag) thereby enabling continuous monitoring of the price situation for policy purposes (Reddy, 1999). The Reserve Bank's policy articulation and inflation projection are, therefore, in terms of WPI (Mohanty, 2010). WPI is superior to the other inflation measure available, consumer price index for industrial workers (CPI-IW), as its coverage of commodities is high and it has a higher frequency.

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The WPI series is available since 1953-54 although the base year has undergone revisions from time to time. Recently, the Reserve Bank has changed the base year from 1993-94 to 2004-05.

The monthly year-on-year inflation from 1953-54 is plotted in Figure 1. A casual glance suggests the following. First, inflation was quite volatile in the initial three decades. Since the 1970s, however, the volatility has declined although there have been occasional spikes in inflation. Second, following the high inflationary episode in the mid-1990s, the inflation rate has moderated although there were two recent spikes in 2008 and 2010.

### IV. Estimation Results

Accounting for lagged and seasonal inflation effects, we use the following GARCH model to obtain the time-varying conditional variance of the error term as our measure of inflation uncertainty:

$$INF_t = \acute{\alpha} + \sum \beta_j INF_{t-I} + \sum \lambda_s INF_{t-s} + \mu_t \qquad (1)$$

Where $INF_t$ is the domestic inflation rate at time $t$, $\acute{\alpha}$ is a constant term, $\mu_t \sim N(0, \sigma^2_t)$ and $\sigma^2_t = \upsilon_0 + \sum \upsilon_i \mu^2_{t-i} + \sum \eta_i \sigma^2_{t-I}$, and $j = 1,2,3,4$ and $s = 6,9,12$. The stochastic error term is denoted by $\mu_t$ while $\sigma^2_t$ is the variance of the error. Several lags of the explanatory variable and autoregressive terms at lags 6, 9, and 12 are included in order to account for seasonality in the data.

Inflation in India is measured by the percentage change in the monthly Wholesale Price Index (WPI). The monthly data on WPI for the 1954:04-2010:04 is collected from the Reserve Bank of India. The use of WPI is motivated by the fact that it is the main measure of the inflation rate in India and is considered as the headline inflation rate. Moreover, previous studies (e.g., Asghar *et al*, 2011) also used this measure.

The summary statistics of the inflation rate in India are given in Table 3 (Panel A). With respect to the third moment, the distribution exhibits positive skewness. In fact, the kurtosis and skewness statistics show that the distribution of the inflation rate is nonnormal and skewed to the right. The large value of the Jarque-Bera statistics indicate deviation from normality. The significant value of the Q(12) statistic and the LM(12) statistic show the presence of ARCH effect.

We next turn to the independence assumption of the inflation series by inspecting whether there is any significant autocorrelation in the first four moments of the series. Panel B in Table 3 presents the results of the Lagrange Multiplier (LM) tests conducted using 6 and 12 lags. The inflation series pass the test at the 10% level. The Kolmogorov-Smirnov test reveals that the inflationary process

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produces unsatisfactory forecasts, since the null hypothesis of unconditional normality is rejected at about the 10% level.

Previous studies using monthly inflation rate raise the possibility of dealing with a trending series and that the trend could be time-varying (McCulloh *et al,* 2000; Patra and Ray, 2010). Consequently, there is a possibility that the monthly inflation series could be a non-stationary process, at most an I(1) series. One way to deal with this issue is to model the series by using the first differenced data. This has two shortcomings. First, Cochrane (1991), among others, has shown that standard unit root tests cannot distinguish between a series with a unit root and one with a near unit root. Second, differencing leads to loss of information and if the assumption of a unit root is not true, over differencing can lead to inefficient parameter estimates (Patra and Ray, 2010).

In the initial stage of the estimation process, the Phillips Perron (P-P) test, the Augmented Dickey Fuller (ADF) test, and the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test are used to determine if the inflation series is stationary. The P-P and ADF tests are of the null hypothesis of a unit root against the alternative of trend stationarity while the KPSS test is based on the null hypothesis of stationarity. However, these tests have been found to be biased toward non-rejection of the null hypothesis in the presence of structural breaks and their low power for near-integrated processes. We, therefore, use the Zivot-Andrews (ZA) test which allows for structural breaks in the series. This test considers the null hypothesis of unit root with no break against the alternative of a stationary process with a break.

Panel A in Table 4 shows the results for the P-P, ADF and KPSS tests. Irrespective of the lag lengths used, all three tests show that the inflation series in India is a stationary series. This is contrary to Asghar *et al* (2011) who found inflation in India to be non-stationary. However, their study only considered quarterly data for the 1987-2008 sample period. In Panel B, the results from the ZA test show that the null hypothesis of a unit root with no break against the alternative of a stationary process with a break is rejected. The break date turns out to be June of 1991 and corresponds to the beginning of the financial liberalization process in India.

Table 5 reports the maximum likelihood estimate of the GARCH model. A lag length of 24 was initially used for the inflation variable and then, following Thornton (2007a), the lag length was shortened based on the Schwartz Bayesian Criterion. The results strongly support the presence of a

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positive relationship between the level of inflation and its uncertainty. The reported coefficients in the inflation and covariance equations are highly significant and are of the expected signs. The positive sign of the intercept in the conditional variance equation is consistent with the non-negativity of the variance. The sum of the ARCH and GARCH coefficients in the conditional variance equation is less than one, which is consistent with the stationarity of the conditional variance of inflation. Also, the coefficient in the covariance equation is always positive and statistically significant. The numerical estimate shows that if inflation increases by one unit, its conditional variance rises by 0.01-0.008. The Q-statistics for the standardized residuals and squared residuals show no patterns. The Ljung-Box $Q^2$ statistics ($LBQ^2$) suggest that including the GARCH parameters is sufficient to remove any heteroscedasticity in the residual. Overall, the GARCH (q,v) model fits well not only the mean, but also the variance process of inflation.

Next, we test for causality between the inflation rate and its uncertainty using a two-step Granger causality test. Recognizing that the choice of lag length may affect the results, both the AIC and SIC information criteria are used to calculate the optimal lag length. Both gave a lag length of 4. Following Conrad and Karanasas (2005), to make sure that the results are not sensitive to the choice of the lag length, we report the causality tests using 4, 8 and 12 lags, as well as the sum of lagged coefficients. Panel A in Table 6 reports evidence on the Friedman-Ball hypothesis; while Panel B reports the results for the causality tests where causality runs from the inflation uncertainty to the rate of inflation. Results from Panel A provide strong evidence in favor of the Friedman-Ball hypothesis. The null hypothesis that inflation does not Granger-cause inflation uncertainty is rejected for all considered lag lengths and the Granger-causal effect is positive. Thus, the Reserve Bank of India should try to stabilize the inflation rate in face of inflationary shocks.

Results in Panel B show that the null hypothesis that inflation uncertainty does not Granger-cause inflation is also rejected for all lag lengths. The effect of inflation uncertainty on average inflation is positive and statistically significant at all lag lengths. The positive effect provides strong support to the Cukierman and Meltzer hypothesis of an opportunistic central bank in India. An implication of this is that the Reserve Bank of India puts greater emphasis on economic growth rather than on inflation stability. However, discretionary policy to stimulate growth should be carefully pursued, as high inflation rates would lead individuals to think that monetary authorities will not curb the inflation rate and this will create even greater inflation uncertainty.

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Devereux (1989) showed that inflation uncertainty can positively affect inflation through the real uncertainty channel. If the main cause for nominal uncertainty is the variability in real shocks, then inflation uncertainty would be positively related to inflation. Higher variability in real shocks lead to a drop in the real degree of indexation. This, in turn, leads to an increase in the inflation rate. Assuming that changes in the degree of indexation occur over time, greater inflation uncertainty precedes higher inflation.

With Granger causality running both ways, there is a feedback process between inflation and inflation uncertainty, so that the Friedman-Ball and Cukierman-Meltzer hypotheses hold simultaneously in India. This is similar to the findings reported on India in Asghar *et al* (2011) but contrary to those reported in Thornton (2007a). Thornton only found support for the Friedman hypothesis in India. Daal *et al* (2005) found support for the Friedman and Holland hypothesis in India.

## V.      Summary and Policy Implications

Inflation and its related uncertainty can impose costs on real economic output in any economy. For an emerging market like India, these costs may be higher than those in developed economies as inflation is still higher than desired. In particular, the population in the lower income strata may find it difficult to hedge against the costs of rising prices and inflation when combined with other distortions in the economy. In order to minimize the adverse economic consequences and welfare costs of increases in the inflation rate, policymakers in India need a clear understanding of the major channels through which inflation may affect the real economy. One such channel comes from the effects that higher inflation has on inflation uncertainty.

This paper contributes to this effort by analyzing the relationship between inflation and inflation uncertainty in India. Initial estimates show the inflation rate to be a stationary process. The maximum likelihood estimates from the GARCH model indicate strong support for the presence of a positive relationship between the level of inflation and its uncertainty.  The Granger causality results report a feedback between inflation and uncertainty. With Granger causality running both ways, the Friedman-Ball and Cukierman-Meltzer hypotheses hold simultaneously in India. It provides strong support to the notion of an opportunistic central bank in India.

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Despite the recent rise in food and other commodity prices, inflation rates have been on a downward trend in India in recent decades. That there is nothing simple about the causes of recent inflation is borne out by the near-term increases in inflation rates across all categories and on both supply and demand factors. During a number of high inflation episodes, both food and fuel prices (reflecting supply-side forces) and the prices of manufactured goods (reflecting demand-side ones) have been on the rise. This raises doubts on the utility of monetary policy alone in addressing these inflation episodes. Historically, too, periods of high inflation has coincided with demand and/or supply-side shocks, with food (mostly internal due to monsoon failures, etc) and fuel supply (mostly external) shocks being the most persistent (see Figure 2). However, unlike the demand-side, supply-side shocks are not amenable to being addressed with conventional monetary and even fiscal policy responses.

This raises the need for automatic fiscal stabilizers and long-term efforts to improve farm productivity, besides more effective counter-cyclical macroeconomic management. As is expected and can be seen from previous experiences, high inflation period have coincided with increases in government borrowings. However, over the past few decades, inflation has remained relatively indifferent of the broad money growth rate (Figure 4). Gokarn (2010) attributes this stability to the increased depth of Indian money markets which have been able to absorb the volumes and mitigated the potentially inflationary pressures. Interestingly, inflation rates have been stable over the last two decades, with inflation volatility dropping sharply (Figures 5).

Our results have some important policy implications. Above all, they point to the benefits of keeping inflation low, stable, and predictable. The goal should be to minimize the marginal effect of inflation on inflation uncertainty. This can be done in a number of ways. First, implement quick policy responses to inflation developments thereby reducing inflation uncertainty both in the short and long run (Caporale *et al,* 2009) and, as Cukierman's prediction holds, persistence (Valdovinos and Gerling, 2011). Second, share information on all major drivers of domestic inflation with the general public in order to help rationalize inflation expectations. Given the importance of food and energy in India's priced index calculation, publishing information on these items as well as exchange rate, inflation rate in major trading partners, projections of important import and export prices, etc. would be beneficial. Third, better explanation of current inflation developments and forecasts to the general public would help to communicate monetary policy stance, anchor inflation expectations and improve the Reserve Bank of India's transparency and accountability. Finally, an

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improved coordination between domestic monetary and fiscal policies would help to react effectively to both demand and supply shocks to the economy.

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**Table 1: Inflation Rate in India: Medium to Long-term**

| Decades | WPI |
|---|---|
| 1951-52 to 1960-61 | 1.9% |
| 1961-62 to 1970-71 | 6.2% |
| 1971-72 to 1980-81 | 10.3 |
| 1981-82 to 1990-91 | 7.1 |
| 1991-92 to 2000-01 | 7.8 |
| 2001-02 to 2009-10 | 5.4 |
| 1971-72 to 2009-10 | 7.7 |
| 1951-52 to 2009-10 | 6.4 |

WPI = Wholesale Price Index

*Source:  Reserve Bank of India*

**Table 2: Double Digit Inflation Episodes in India: Causal Factors**

| Period | No. of Months of Double Digit Inflation | Causal Factors |
|---|---|---|
| April 1956-February 1957 | 11 | Drought and decline in agricultural output for 2 years; investment demand pressures |
| August 1964-February 1965 | 7 | India-Pakistan War; Drought |
| March 1966-November 1967 | 21 | Drought for 2 years; Rupee devaluation |
| October 1972-March 1975 | 30 | Drought; India-Pakistan war; First oil price shock; Higher global grain and metal prices; Large monetary expansion |
| June 1979-August 1981 | 26 | Drought; Second oil price shock; Global inflation |
| November 1990-July 1992 | 21 | Drought; Increase in the prices of administered items and excise duties; Cumulative impact of large fiscal deficit |
| March 1994-May 1995 | 15 | Substantial hike in administered prices; Shortfalls in the production of cash crops; Large fiscal deficits and monetary expansions |
| June 2008-October 2008 | 5 | High global commodity prices; Large credit expansion for 3 years |
| March 2010-July 2010 | 5 | Drought; Administered price increases; Reversal of global commodity prices after fall during global financial crisis. |

*Source: Mohanty (2010)*

## Table 3: Summary Statistics for WPI (Period 1954:04-2010:04)

*Panel A: Descriptive Statistics*

| | |
|---|---|
| Mean | 0.064 |
| Standard deviation | 0.068 |
| Kurtosis | 14.776 |
| Skewness | 5.062 |
| Jarque-Bera | 88.46 (0.000) |
| $Q^2_{12}$ | 79.654 (0.000) |
| LM(12) | 75.198 (0.000) |

*Panel B: Normality and Autocorrelation Tests*

| | |
|---|---|
| Kolmogorov-Smirnov Test Statistic | 0.096 (0.085) |

Autocorrelation Tests

| | 1st Moment | | 2nd Moment | | 3rd Moment | | 4th Moment | |
|---|---|---|---|---|---|---|---|---|
| Lags | 6 | 12 | 6 | 12 | 6 | 12 | 6 | 12 |
| | 0.16 | 0.23 | 0.22 | 0.26 | 0.50 | 0.48 | 0.46 | 0.67 |

Note: Jarque-Bera is the statistics for normality; $Q^2_{12}$ is the 12th order Ljung-Box test for serial correlation in the squared residuals of the inflation rate from its sample mean; LM(12) is the chi-square test statistic for ARCH effects with 12 degrees of freedom. The figures in parentheses are the p-values. See Thornton (2007a) for further notes.

For Autocorrelation tests, p-values of the LM tests correspond to the null of no auto-correlation in the first four moments.

**Table 4: Unit Root Test Statistics**

*Panel A.      Unit Root with no Structural Break*

| Lag | P-P | ADF | KPSS |
|-----|-----|-----|------|
| 0 | -5.34 | -4.98 | 0.32 |
| 6 | -8.44 | -6.15 | 0.43 |
| Optimal | -9.12 | -8.04 | 0.45 |

*Panel B: Zivot-Andrews test with one Structural Break*

| Test Statistics | Break Date |
|-----------------|------------|
| -6.942 | 1991:06 |

- Note: P-P is the Phillips-Perron test, ADF is the Augmented Dickey Fuller Test and KPSS is the Kwiatkowski-Phillips-Schmidt-Shin test. In case of both the P-P and ADF test, the null hypothesis is the presence of a unit root in the series; while in the KPSS test the null hypothesis is the presence of stationarity.  The Zivot-Andrews test considers the null hypothesis of unit root with no break against the alternative of a stationary process with a break. The lag length for the ADF test is selected on the basis of the Akaike's Information Criterion while those for the P-P test and KPSS is selected on the basis of the Newey-West Criterion. The t-test is used to select the optimal lag length in case of the Zivot-Andrews test.

**Table 5: GARCH(q,v) model for Inflation and Inflation Uncertainty in India**

Inflation Equation AR(p):

$$\prod_t = 0.013 + 0.253p(-1) + 0.166p(-2) + 0.354p(-3) + 0.183p(-6)$$
$$\quad\;\, (0.004)\;\;(0.043)\qquad\;(0.021)\qquad\;\;(0.016)\qquad\;\;\;(0.022)$$

$$+ 0.354p(-9) + 0.239p(-11) + 0.195p(-12)$$
$$\;\;(0.012)\qquad\;\;(0.048)\qquad\;\;(0.051)$$

Variance Equation

|  | Estimate (p-value) |
|---|---|
| Intercept | 0.005 (0.000) |
| ARCH(1) | 0.224 (0.032) |
| GARCH(1) | 0.460 (0.024) |
| P | 0.004 (0.001) |

*Diagnostics*

|  |  |
|---|---|
| Adj. $R^2$ | 0.64 |
| Standard error | 0.008 |
| SBC | -6.32 |
| Q(4) | 2.944 (0.320) |
| $Q^2$(4) | 1.476 (0.688) |
| Q(12) | 4.657 (0.562) |
| $Q^2$(12) | 3.988 (0.464) |
| LM(4) | 0.812 |
| LM(12) | 0.926 |
| $LBQ^2$ (1) | 0.56 |
| $LBQ^2$ (3) | 1.65 |
| $LBQ^2$ (6) | 3.22 |

SBC= Schwartz Bayesian Criterion; Q(k) and $Q^2$(k) are the Box-Pierce statistics of the levels of the residuals and the squared residuals, respectively; LM(4) and LM(12) are ARCH LM test statistics of chi-square(4) and chi-square(12), respectively. The figures in parentheses are the p-values. See Thornton (2007a) for further notes. The critical values for the $LBQ^2$ statistic for lags 1, 3, and 6 at the 5% level are 3.84, 7.81 and 12.59 respectively.

**Table 6: Granger Causality Tests between Inflation and Inflation Uncertainty**

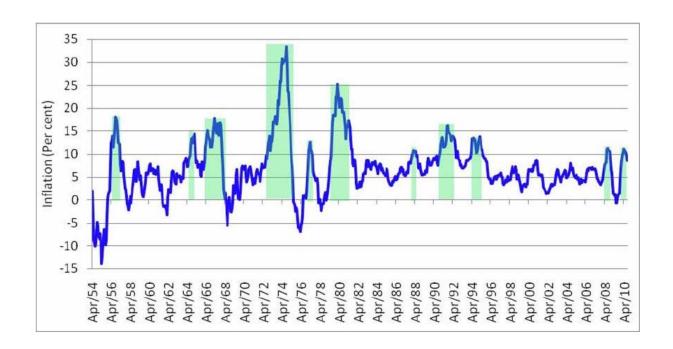*Panel A:*       $H_0$: *Inflation does not Granger-cause Inflation Uncertainty*

| Lag (VAR order) | F Statistics |
|---|---|
| 4 (6) | 12.62** (+) |
| 8 (10) | 21.34** (+) |
| 12  14) | 26.23** (+) |

*Panel B:*      $H_0$: *Inflation Uncertainty does not Granger-cause Inflation*

| Lag (VAR order) | F Statistics |
|---|---|
| 4 (6) | 14.46** (+) |
| 8 (10) | 24.90** (+) |
| 12 (14) | 30.65** (+) |

Note:  The number in the first column gives the lag structure and in parentheses the order of the VAR. A (+) sign indicates that the sum of the lagged coefficient is positive. ** denote significance at the 0.05 level.

**Figure 1: WPI Inflation Rate 1954-2010**



*Source: Mohanty (2010)*
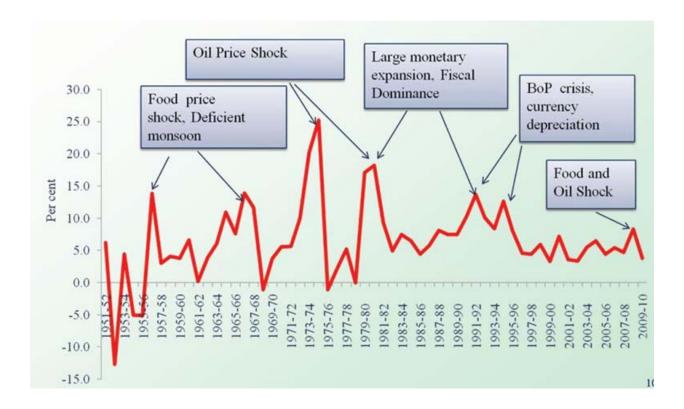
Figure 2:  Major Sources of High Inflation



*Source: Gokarn (2010)*
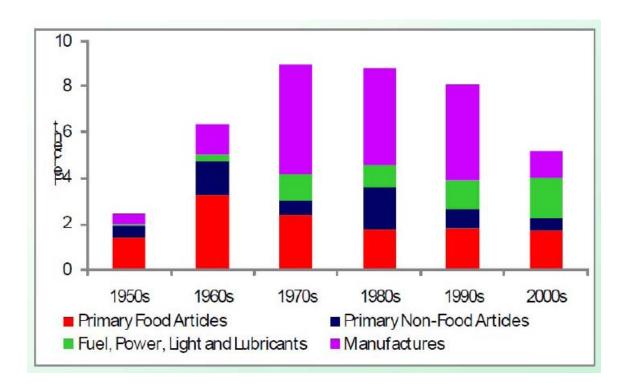
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**Figure 3: Sources of Inflation**



*Source: Gokarn (2010)*

**Figure 4:  Monetary and Fiscal Drivers of Inflation**



*Source: Gokarn (2010)*

**Figure 5: Growth, Inflation and Volatility in Inflation**



*Source: Gokarn (2010)*