

Inflation, Inflation Uncertainty and Output Growth in India

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IN

ECONOMICS

BY

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DECLARATION

I, **CHODAGANGA SAHU** hereby declare that the work embodied in the present dissertation entitled "*Inflation, Inflation Uncertainty and Output Growth in India*" carried out under the supervision of **Prof. Debashis Acharya**, School of Economics, for the award of Master of Philosophy in Economics from University of Hyderabad, is a bona fide research work, which is also free from plagiarism. I also declare that it has not been submitted previously in part or full to this University or any other University or Institution for the award of any degree or diploma. I hereby agree that my thesis can be deposited in Shodganga/INFLIBNET.

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This is to certify that the research embodied in the present dissertation entitled “*Inflation, Inflation Uncertainty and Output Growth in India*” has been carried out by *Chodaganga Sahu* under my supervision for the full period prescribed under M. Phil. ordinances of the university.

This thesis or a part thereof has not been previously submitted for the award of any degree or diploma at this or any other University/Institute.

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Dedicated to

My Parents

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Chapter-I

Introduction, Objectives, and Scope of the Study

1.1 Introduction

Price stability is one of the major aims of central banks around the world. A stable, predictable inflation is considered to be good for achieving long-run economic growth, financial stability and efficiency.¹ The Federal Reserve Bank chairman Ben Bernanke argued that “the low-inflation era of the past two decades has seen not only significant improvements in economic growth and productivity but also a marked reduction in economic volatility, both in the United States and abroad, a phenomenon that has been dubbed "the Great Moderation.”²

There are two line of research on relationship between economic growth and inflation is available, the one line is concerning about the trade-off between inflation and economic growth and other is concerning the relationship between growth, inflation and their uncertainty. Bruno and Easterly (1998) showed that higher inflation has a negative impact on growth and growth recovers rapidly when inflation falls. Stanner(1996) and Stanner (1993) argued that, there is no evidence for the support of the argument that low inflation is associated with higher growth. There is another kind of consensus regarding the relationship between growth and inflation that is inflation affects growth when inflation reaches a certain threshold level. Sarel (1995) investigated the nonlinear effect of inflation and growth, and he found that inflation impede growth when it reaches 8 percent, below which the impact is slightly positive. Khan and Senhadji (2001) in their analysis showed that the threshold effects for developing economies are 11 to 12 percent and for developed economies 1 to 2 percent. So, there is no common consensus exist regarding the relationship between growth and inflation.

¹ See Bernanke(2011)

² See Bernanke(2004) <http://www.federalreserve.gov/Boarddocs/speeches/2004/20041008/>

Since the publication of Okun (1971), a large attention has been paid for the analysis of inflation, growth and their uncertainty. He argued that Inflation volatility is the unobservable, unforeseen and random component in the time series process, which can cause significant social cost due to its unpredictability. A highly volatile inflation can lead to distort the price signaling mechanism and thereby misallocation of resources. This persistence in inflation volatility reduces saving, investment as the long term contract become more uncertain and it in turns impede economic growth.

There are many competing theories regarding the relationship between uncertainty growth and inflation. The Chapter-2 reviewed those theoretical arguments and brings out six line of causal relationship between inflation, inflation uncertainty and economic growth. These entire hypotheses and the corresponding theatrical literature are presented below in table 1.1.

1.2 Objectives

The main objectives are

- 1- To examine the nexus between inflation and inflation uncertainties in Indian context
- 2- To examine the relationship between inflation uncertainty and economic growth in the Indian context.

1.3 Relevance of the study

In case of India, there is paucity of studies on the relationship between economic growth, inflation and their uncertainty. Choudhury (2011) and Thornton (2005) both found that the Cukierman-Meltzer hypothesis and Friedman-Ball hypothesis hold simultaneously for India. However, their analysis relied on simple symmetric GARCH models; there might be asymmetric effects in inflation volatility. They also did not investigate the effects of inflation uncertainty on economic growth. So, against this backdrop, this thesis aims to analyses in a more comprehensive way by analyzing both symmetric GARCH and asymmetric GARCH models.

Table 1.1

Hypothesis	Theoretical literature
1- Inflation positively causes inflation uncertainty	Friedman (1977), Okun (1971) , Ball (1992)
2- Inflation uncertainty positively causes inflation	Cukierman and Meltzer (1986)
3. Inflation reduced inflation uncertainty.	Pourgerami and Makus (1987), Ungar and Zilberfarb (1993).
4- inflation uncertainty reduces inflation	Holland (1995).
5- Inflation uncertainty reduces output growth	Friedman (1977), Fischer and Modigliani and Pindyck(1991)
6- Inflation uncertainty positively causes growth	Dotsey and Sarte (2000)

1.4 Data and Methodology

The monthly data of Index of Industrial Production (IIP) and Wholesale price Index (WPI) is used³. Both the WPI and IIP data are converted to 1993-94 base year prices and seasonally adjusted. Inflation is measured as the logarithmic monthly difference of the wholesale price index as $\pi_t = \log (WPI_t/WPI_{t-1}) * 100$ and similarly, output growth is logarithmic monthly difference of industrial production index as $g_t = \log (IIP_t/IIP_{t-1}) * 100$. This study follows the methodology of Grier and Perry (1999) and Berument et al. (2009).⁴

³ Data is seasonally adjusted using X-12ARIMA methods.

⁴ Discussed in chapter-3 in details.

1.5 Organization of the study

This thesis consists of five chapters. In chapter-1, which is this chapter, an overview of the thesis has been presented. A brief review of inflation growth tradeoff and the relation between their uncertainty, objective, methodology and limitation of the study are also discussed.

Chapter 2 has reviewed the theoretical and empirical literature on the relationship between inflation, its uncertainty and growth. The methodological issue of measuring the inflation uncertainty also discussed in this chapter.

The methodology used to empirically analyses the inflation, inflation uncertainty and growth discussed in details in chapter-3

Chapter 4 contains the empirical analysis of the causal nexus between inflation, inflation uncertainty and economic growth. Finally, concluding remarks and limitation of the study are given.

1.6 Limitations of the study

The study uses the monthly increases in Index of Industrial production as a proxy for economic growth due to non-availability of GDP the data. The models undermine the influence of other important variables which may have significant effects on volatility. The other sources of volatility due to structural changes are also ignored in the study. This study is primarily dealt on time domain analysis ignoring the frequency domain analysis.

Chapter-II

Review of Literature

2.1 Introduction

This chapter reviews the theoretical literature on the nature of the relationship between inflation, inflation uncertainty and economic growth. Subsequently country specific and region specific empirical evidence regarding the relationship between inflation, inflation uncertainty is discussed in details. As inflation uncertainty is stochastic and directly unobservable, various methods are used to construct a convincing measure of inflation uncertainty. These methods are also discussed in this chapter in details.

2.2 Theoretical Literature

Okun (1971) was one of the first to study the possible effect of inflation uncertainty in a very informal discussion, ascertaining on the importance of political instability to influence people expectation regarding inflation and its future uncertainty. Hence, he argues that higher inflation in the current period will lead to heightened uncertainty regarding future inflation as a result of government distorted policy and lack of credibility.⁵ Friedman (1977) argues that unpredictable policy changes by the monetary authority during a higher inflationary period likely to create inflation concerning the future inflation rate. During higher inflation periods, policymaker faces political pressure to reduce inflation while policymakers reluctant to choose a contractionary monetary policy to counter higher inflation. So, in this way general public fails to foresee the future because the monetary policy becomes unpredictable and hence contribute to heighten inflation uncertainty. This intuitive argument was formalized by Ball (1992) in a game

⁵ See Okun (1971)

theoretical framework with asymmetric information between public and policy makers. This argument of Friedman and Ball regarding the positive correlation between inflation uncertainty and inflation is popularly known in the empirical literature as “Friedman-Ball hypothesis”.⁶

Meltzer and Cukierman (1986) propose a different causal between inflation and inflation uncertainty causal link by using a “time-consistent” argument in the of “Barro-Gorden model”.⁷ In Meltzer-Cukierman (1986) model both policymaker objective and monetary growth are the random variables. The monetary policymaker maximizes his own objective function, which is positively related to economic stimulation through monetary surprises and negatively related to monetary growth. They argue that, due to imprecise monetary control error, public fails to distinguish between policy objective and a temporary change in monetary control error, therefore, public faces inferences problem observing an intentional increase in inflation. This higher uncertainty raises inflation because it provides the incentive to the policymakers to benefit from inflation by an expansionary monetary policy with the intention to surprise the economic agent. In the model of Cukierman-Meltzer, higher inflation uncertainty causes inflation whereas in Friedman argument higher inflation leads to higher inflation uncertainty.

Pourgerami and Makus(1987) argue that a higher level of inflation induces economic actor to invest more on gathering information for accurate prediction of the future course of inflation and thereby reducing inflation uncertainty. Hence, they demonstrated a negative association between inflation and inflation uncertainty that challenges the Friedman-Ball hypothesis of a positive association between inflation and inflation uncertainty. Ungar and Zilberfarb (1993) theoretically demonstrated the hypothesis of Pourgerami and Makus (1987) by employing both rational expectation and adaptive expectation with the assumption that, agent spend more resources on the prediction of inflation when there is a rise in inflation.

⁶ See Grier and Perry (1998), Fountas(2001), Daal and Naka(2005), Hartmann and Herwartz (2012)

⁷Robert J and Gordon. (1983) <http://www.nber.org/papers/w1079>.

In contrast to the Cukierman- Meltzer (1986) hypothesis, Holland (1995) draws a different argument for the negative association between inflation and inflation uncertainty based on the stabilization motive of the monetary authority popularly known as “stabilizing fed hypothesis”. He argues that increasing inflation leads to higher inflation uncertainty and monetary authorities respond by contracting the money supply growth in order to eliminate inflation uncertainty and associated negative welfare cost. Hence, higher inflation uncertainty leads to lowering inflation because of stabilizing the behaviour of the central bank in a high inflation uncertainty period.

A higher level of inflation spring up from higher price level causes significant social cost on the economy because of the adverse redistributive impact of high level of inflation and uncertain move in the prices. A low stable, predictable and fully anticipated inflation causes minor social and economic cost. The price system provides signals to the economic agent both producer and consumer to allocate their resources in a more efficient manner either in good services and factor of production. A high unanticipated inflation creates chaos and distorts this signaling mechanism and creates a significant social cost in terms of lowering the investment as return on investment becomes uncertain and their by reducing economic growth.

Although Freedman (1977) Nobel lecture was largely devoted to the discussion on the relationship between inflation and unemployment, but he draws a certain argument regarding the correlation between inflation uncertainty, inflation and economic growth. He argues that higher inflation volatility leads to an uncertain monetary policy to counter it this will further lead to widening the gap between actual and anticipated inflation. This widening gap between actual and anticipated inflation will lead to a distortion in the allocation of resources and hence inefficiency and lower economic growth.

Fisher and Modigliani (1978) argue that inflation uncertainty hinders long-term contract and thereby reduces the rate of investment. As a consequence of lowering in the rate of investment, it hinders real economic activities. In a similar fashion Pindyck (1991) argue that “When investment is irreversible and future demand or cost conditions are uncertain, investment expenditure involves the exercising, or "killing," of an option to productively invest at any time in the future. One gives up the possibility of waiting for new information that might affect the desirability or timing of the expenditure; one cannot disinvest should market conditions change adversely”. So, according to Pindyck (1991), the real and nominal uncertainty could lead to heightening uncertainty on the potential return of investment and hence adversely affect the real economic activities.

Contrary to Friedman (1977), Fisher and Modigliani (1978) and Pindyck (1991) arguments Dosrste and Sarte (2000) depict a positive association between inflation uncertainty and economic growth. They use an AK type production technology with cash-in-advance constraint that allow for precautionary saving and risk-aversion. They argue that a higher variability of inflation triggered by increased monetary growth makes uncertain to return on money balances. This could lead to a fall in the demand for real money balances and consumption and higher precautionary saving available to pool for investment purposes.

2.3 Some testable hypothesis from the theoretical literature

From the above discussed theoretical literature, there are six possible hypotheses on the relationship between inflation uncertainty, inflation and economic growth. These hypotheses are widely studied in the empirical literature. This testable hypothesis and correspondingly the theoretical literature are represented in the table table2.1.

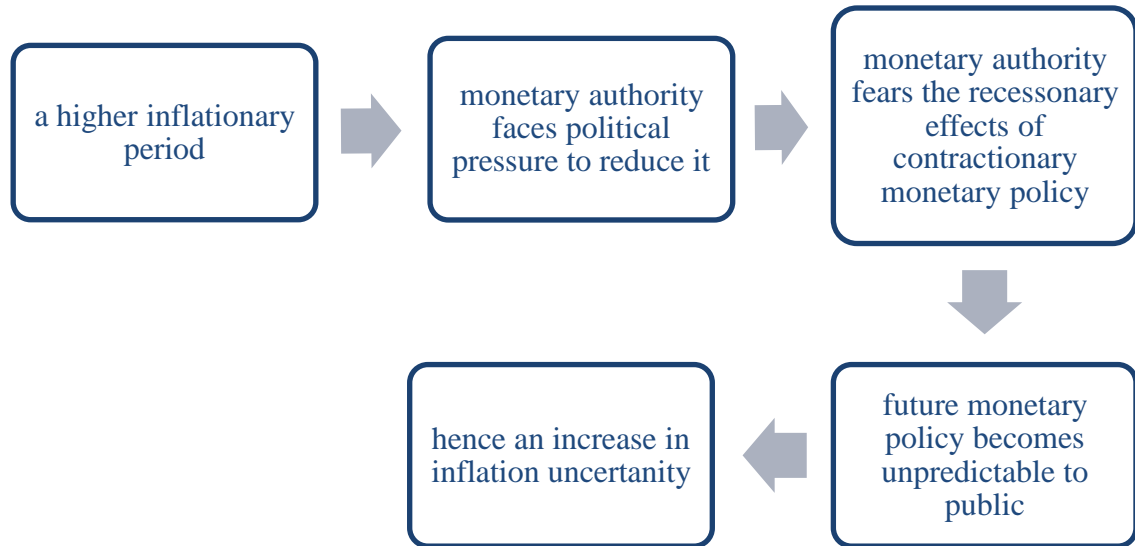
Table2.1

Hypothesis	Theoretical literature
1- Inflation positively causes inflation uncertainty	Friedman(1977),Okun(1971) , Ball(1992)
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3. Inflation reduced inflation uncertainty.	Pourgerami and Makus(1987) , Ungar and Zilberfarb (1993).
4- inflation uncertainty reduces inflation	Holland (1995).
5- Inflation uncertainty reduces output growth	Friedman(1977), Fischer and Modigliani(1978), Pindyck(1991)
6- Inflation uncertainty positively causes growth	Dotsey and Sarte(2000)

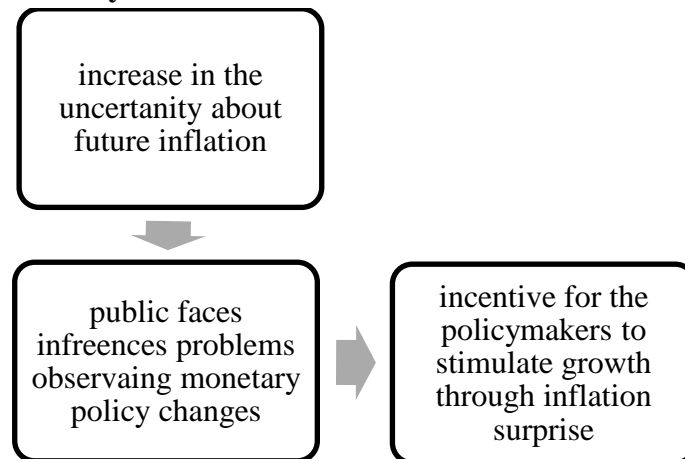
2.4 Mechanism of Inflation uncertainty

For a better understanding of the above-stated hypothesis, these hypotheses are represented in flow charts.

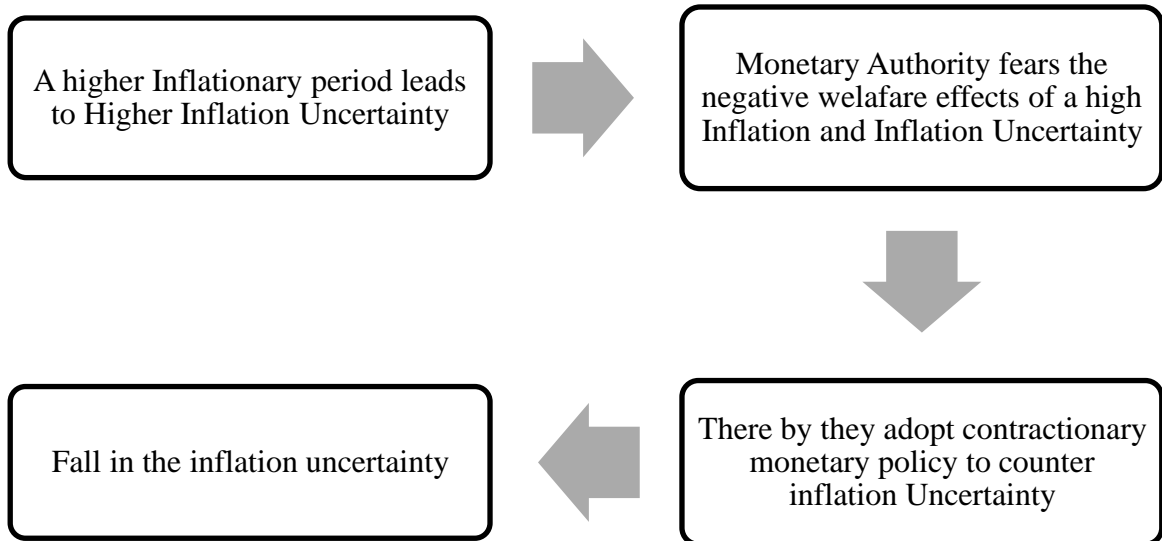
Hypothesis 1: Higher inflation causes high inflation uncertainty Friedman (1977)



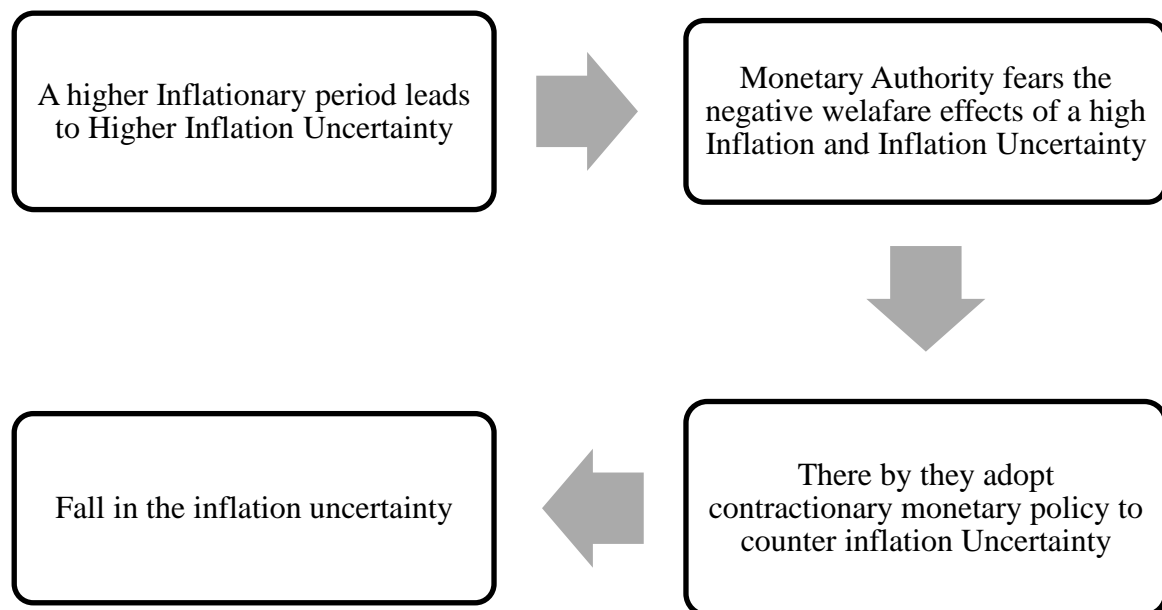
Hypothesis 2: Inflation uncertainty raises inflation Cukierman and Meltzer (1986)



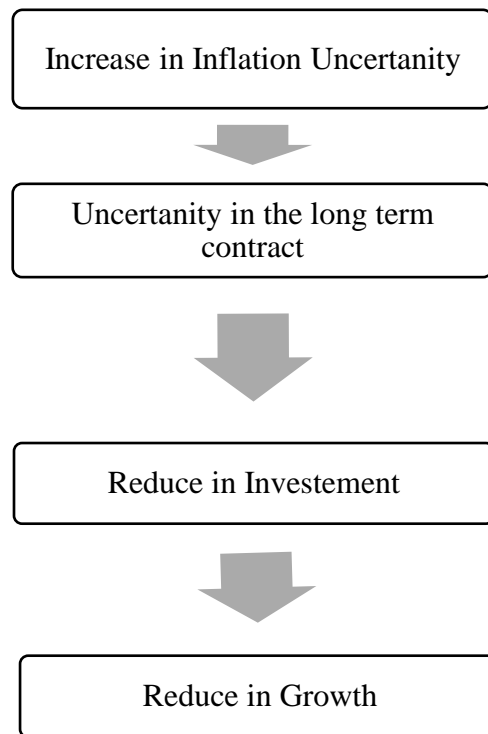
Hypothesis 3: Higher inflation reduces inflation uncertainty by Pourgerami and Makus(1987) and Ungar and Zilberfarb (1993).



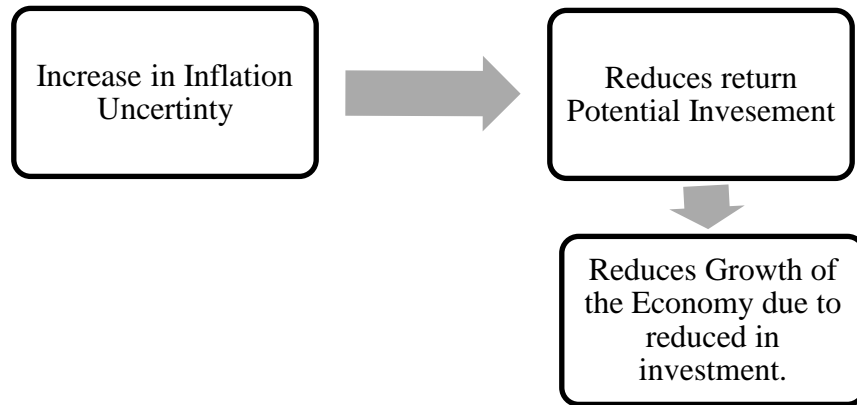
Hypothesis 4: Higher inflation leads to falling in inflation uncertainty the Holland (1995) stabilizing fed hypothesis.



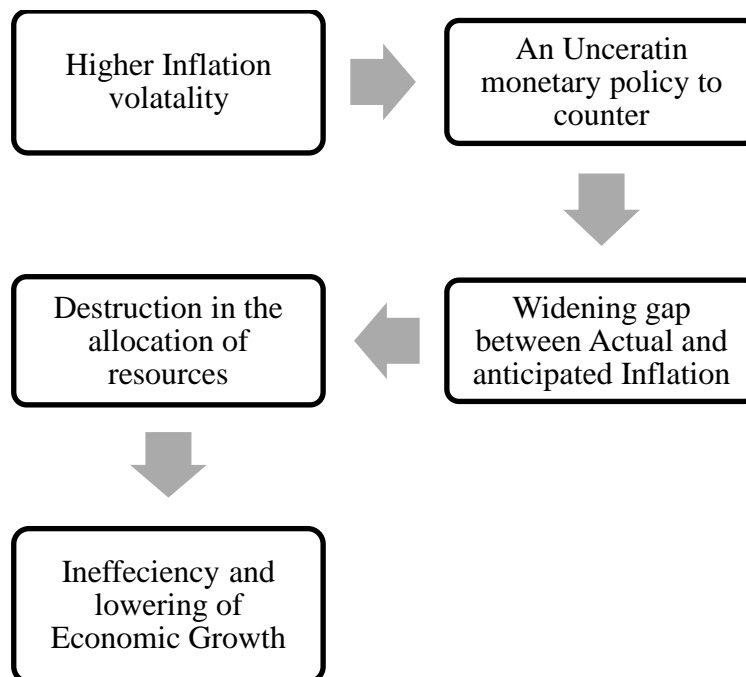
Hypothesis 5: inflation uncertainty reduces output growth argued by Pindyck (1991)



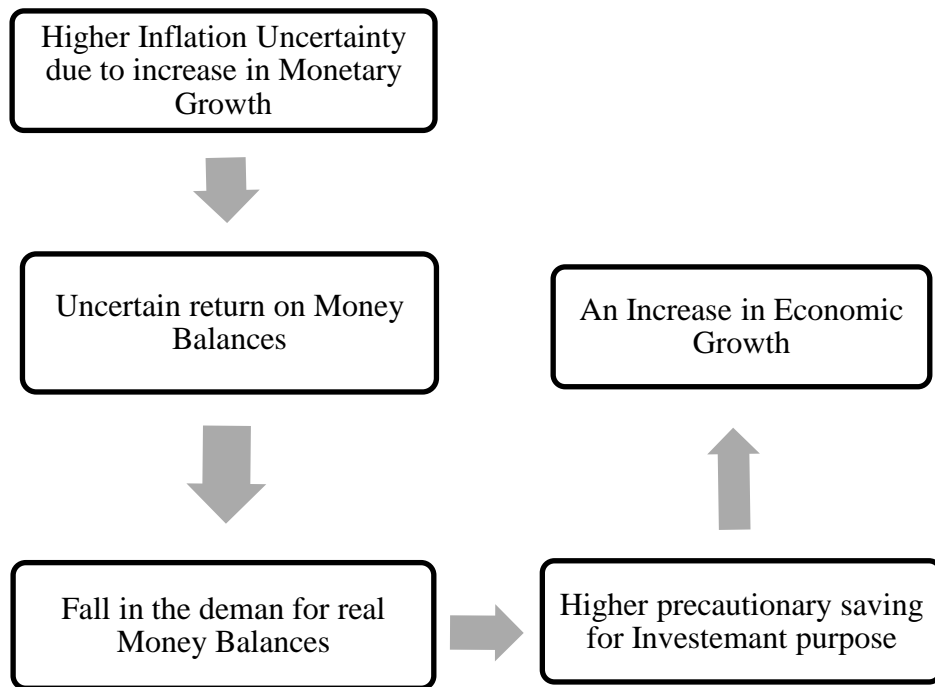
Hypothesis 5: inflation uncertainty reduces economic growth. The channels argued by Fisher and Modigliani(1978).



Hypothesis 5: Inflation uncertainty reduces output growth as argued by Friedman (1977)



Hypothesis 6: inflation uncertainty leads to economic growth the channel through which inflation uncertainty affect output growth argued by Dotsey and Sarte (2000).



2.5 Review of Empirical Evidence

Early studies by Okun (1971), by using the standard deviation of increase in GNP deflator annual data of OECD countries confirms that inflation positively associated with inflation uncertainty. He argued that, since monetary policy becomes more unpredictable during the time of inflation, high inflation tends to produce high inflation uncertainty.

After the publication of Okun (1971) and Friedman (1976), a plethora of research papers published concerning the relationship between inflation and inflation uncertainty. Longue

and Willett (1976) examined the relationship between inflation and inflation variability using cross-section annual data of 41 countries. He found that high inflation is associated with high inflation variability, confirming the previous study by Okun (1971). He also added that the association between inflation and inflation variability for industrialized countries was found to be weak.

Using the price of consumer goods, Park (1978) analyzed the relationship between inflation and relative price variability for Netherlands and United States for the period 1929 to 1975. By employing a multi-sector supply and demand framework, he concludes that the amount of unanticipated inflation has a greater impact on the relative price variability than the inflation.

Foster (1978) used average absolute change as inflation unpredictability rather than variance as a measure of the inflation variability. He found that inflation raise inflation variability. Biljer (1979) confirmed the earlier findings of Okun (1971), Foster (1978), Willet (1976) holds for a number of Latin-American countries. Tylor also found that inflation raise high inflation variability.⁸Hefner and Hefner (1981) analyzed the linkages between inflation and inflation variability for some 40 diverse economies. Their findings confirm the previous findings of Biljer (1979) that the industrialized the relationship found to be weak. He also found that the threshold level of inflation risen 9 percent as opposed to previously found results of 4 percent during the 1970s.

Most of the studies discussed above have used variance inflation as a proxy for the inflation unpredictability. Variance inflation may not be an appropriate measure of the inflation unpredictability if economic agents base their expectation on other past variable as opposed to only past variability of inflation and if these variables are predictable then inflation variability can hardly capture the unpredictability of inflation. Based on this argument some early studied have used absolute forecast error for the measurement of

⁸ The previous studies in the 70s and 80s, for the analysis of unanticipated inflation, either moving standard deviation or survey-based forecast measures were used.

unpredictability and subsequent analysis of the relationship between inflation unpredictability and inflation.⁹

Forham et al. (1981), Glezakos and Nugent (1986) used absolute forecast error to examine the relationship between inflation unpredictability measured by absolute forecast error and inflation. Their results demonstrate a significant and positive effect of inflation unpredictability and inflation for The United States between the periods 1954 -1979. The analysis of Glezakos and Nugent (1986) found similar results obtained by Forham et al. (1981) for seven Latin-American countries by using quarterly data for short-horizon and annual data for long-horizon.

Empirical evidence regarding the causal relationship between inflation uncertainties and inflation is ambiguous and mixed. There are ample of empirical research available on G7 countries regarding the causal link of inflation and its uncertainty. Grier and Perry (1998) empirically examined the relationship between inflation uncertainty and inflation for G7 countries for the period 1949-1993.¹⁰ They first analyzed the economy of US using the consumer price index data (CPI) by employing simple symmetric GARCH model and asymmetric GJR and component GARCH model. The asymmetric coefficient of GJR model found to be insignificant and, they detected that the coefficient of simple GARCH and component GARCH models are highly correlated. Subsequently, they extended their analysis to the by using monthly consumer price index data from the period 1948 to December 1993. The asymmetric effect was not found in any of the six countries. Except Canada and The UK, long memory model found to be improving the process of estimation. The effect of inflation uncertainty on inflation varies across countries. High and significant negative impact of inflation uncertainty found in the case of Germany supporting the Friedman-Ball hypothesis. This negative relationship between inflation uncertainty and inflation is found to be weak in case of UK. Holland's (1995) argument

⁹ See Forham et.al(1981), Glezakos and Nugent(1986)

¹⁰ Germany, Japan, UK, Canada, France, Italy

for the stabilization motive of the central bank, when shocks raise inflation uncertainty, is supported by the UK and Germany. The effects of inflation uncertainty on inflation found to be insignificant in case of Canada and, the results for the Italy found to be varied across various lag length.

Unlike the above discussed papers, Bhar and Hamori (2004) took a slightly different approach and methodology to study the interaction between inflation and inflation uncertainty for G7 countries. They used a Markov-switching conditional heteroscedasticity model to examine the causal relationship both in short and long horizon. They argued that the formal symmetric and asymmetric model undermines the importance of uncertainty and unpredictability of changes in inflation that arises from possible structural change. They apply the Markov-switching conditional heteroscedasticity model to the quarterly price data of the G7 economies from the first quarter of 1961 to the fourth quarter of 1999. Due to the unavailability by GDP deflator data for the sample period they took for study, they used consumer price data for Germany and Italy, for the rest of the countries, i.e. Canada, USA, Japan, France and UK they used GDP deflator data. From their estimated results they found that the trend component contributes to the persistence of the shocks for Canada, France U.S.A., Italy, Japan, Germany, and the U.K. The transitory component contributes to significant persistence of shock for, France, U.K Germany, U.S.A., Italy, Japan, and the Canada. So, for countries like Italy and Japan they found that the persistence of the conditional volatility caused by bot transitory and permanent component. From their empirical analysis they found that the positive shift in inflation is triggered by high uncertainty about the long run inflation for Germany, Canada and japan supports for Friedman-Ball hypothesis. They argued that if the level of inflation rises from the normal, this leads to rise in the uncertainty level and tends to produce an unstable monetary policy. They showed that short-run rise in inflation found to be positively contributing to inflation uncertainty for USA, and Germany and negatively contributing to rise in inflation uncertainty to Canada. For Germany, transitory component found to be positively correlated with inflation uncertainty and negatively correlated for Canada. They found

that the transitory shock is lower as compared to the ratio of low variance in the permanent shock to the transitory shocks for USA and lower for U.K, Canada, Japan and France. Their results show that the interaction between inflation and inflation uncertainty is different in different time horizons and lag lengths.

Fountas et.al (2006) analyzed the interaction of inflation uncertainty inflation and economic growth for Group-7 countries. They used a bivariate constant conditional correlation CCC- GARCH model to construct the series of uncertainty. They use price data of the Production of Price Index (PPI) and their annualized monthly log difference is constructed as inflation and economic growth. Except France and Italy, the negative welfare effect of inflation uncertainty on economic growth proposed by Friedman-Ball found to be significant. The evidence was found to be strong for Canada, UK, and Japan. The impact was found to be weak for Germany at different lag lengths.

Fountas and Karanosas (2007) used a univariate GARCH model of inflation along with Granger causality test to study the causal relationship between inflation uncertainty and inflation for G-7 countries covering a period from 1957 to 2000. For the economy, US they used monthly data of consumer price index (CPI) and Index of Industrial production (IIP) proxy for the price level and economic growth. They found that the symmetric-GARCH models are inferior to the asymmetric-GARCH in explaining the time varying conditional variability in the inflation series. The leverage effects of the asymmetric models are found to be negative. The positive shocks are capable of predicting higher negative shocks. They found that Friedman- Ball hypothesis hold the US economy, that is, higher inflation leads to high inflation uncertainty and inflation uncertainty does not cause negative output growth for US economy. When they used producer price index (PPI) instead of consumer price index (CPI), they found that the Friedman-Ball and Cukierman-Meltzer hypothesis still hold. They pointed out that, the Friedman-Ball hypothesis hold for only one lag when CPI index is used, and when PPI index is used the Friedman-Ball hypothesis is hold for both one and two lag. The overall result is that the

inflation uncertainty is independence to economic growth. Further they extend their analysis to G-7 countries. They tested the efficacy of both symmetric and asymmetric-GARCH model to explain the volatility for G7 countries and they found that asymmetric-GARCH model found to be more convincing in explaining the inflation volatility. This means that negative and positive shock of inflation have a different impact on inflation uncertainty. Their results shows that for France, Japan, Italy, and the UK the asymmetric coefficient is found to be negative that means implying negative shocks leads to more uncertainty as compared to positive shocks. The reverse is found in case of for Canada and Germany, negative shocks leads to more volatility than a positive shocks. They use granger causality to establish the causal relation between inflation and inflation uncertainty and economic growth. The first lag Friedman-Ball hypothesis is supported by all countries except Germany. This results show sharp contrast to previously found results of Grier and Perry (1998), where for Germany, inflation uncertainty leads to heighten inflation, supporting Friedman-Ball hypothesis. For Germany and the UK, inflation uncertainty found to be costly, reducing economic growth. For Canada and Japan the inflation uncertainty leads to higher inflation supported the Dotsey and Sartre (2000) hypothesis. The hypothesis of Cukierman-Meltzer that is higher inflation uncertainty leads to high inflation is supported in Germany. Strong evidence for the Holland “stabilizing fed” hypothesis is found for the Canada. For Italy, Japan and UK, the evidence found to be mixed at different lags.

Whereas Cermeño and Grier (2006) used a dynamic panel data along with a conditional heteroskedastic model to the monthly inflation data of G7 countries over the period February 1978 to September 2003. They found a very high inflation volatility and cross-sectional dependence. They also found that inflation was unpredictable as higher inflation was associated with high inflation uncertainty in supports of Friedman-Ball hypothesis. Stabilization motive of the central bank was found to be stronger than the opportunistic behaviour of the central bank in all the countries.

The United States is one of the most studied economy regarding the Friedman-Ball and Cukierman-Metzler hypothesis. Grier and Perry (2000) found no evidence that the higher inflation uncertainty raises average inflation and vice versa refuting the hypothesis of both Friedman-Ball and Cukierman and Metzler for US economy. On the other hand Grier (2004) analyzes post-war data of US covering the period from 1974 to 2000 with a bivariate GARCH-M, supplemented by impulse response to evaluate the nominal and real uncertainty on inflation and economic growth; they found a contradictory result of their previous study. Their result shows that higher inflation uncertainty leads to lowering inflation in support of Holland (1995) argument of stabilizing the behaviour of the central bank. Fountas and Berdin (2005) using monthly data covering the period from 1957 to 2003 don't find any evidence consistent with the Cukierman - Metzler hypothesis. Bhar and Mallik (2010) used a multivariate EGARCH-M, supplemented by impulse response function; found that inflation uncertainty has a positive and significant effect on inflation for US economy. Conrad and Karnasos (2005) used a long memory ARFIMA-FIGARCH model to study Japan, UK and The USA and found a strong evidence of Friedman argument and a feedback relationship in inflation and inflation uncertainty for Japan.

Empirical studies on United Kingdom by Fountas (2001), Kontanikas (2004), Karnasos (2005) shows that heightened inflation is associated with a high uncertainty about future inflation in support of the Friedman-Ball causal link. Kontanikas (2004) empirically examined the causal link of inflation and inflation for the UK economy. He used the seasonally adjusted log of consumer price index to measure inflation and the time varying conditional variance of inflation obtained from component GARCH-M, symmetric and asymmetric GARCH models as the proxy for inflation uncertainty. The evidence from his analysis using threshold GARCH (TGARCH) model by employing an inflation targeting dummy in the TGARCH model, the coefficient found to be negative and significant, suggest that inflation uncertainty has reduced after the adaption of inflation targeting. The same results are found in the component GARCH-M (CGARCH-M) model, the dummy coefficient of the inflation targeting (IT) found to be negative and significant. He also argues that the adoption of explicit inflation targeting has the advantage of eliminating inflation persistence by reducing uncertainty about future inflation.

In recent years, Turkey is one of the most studied economy regarding the inflation and inflation uncertainty nexus. Regarding the hypothesis of Friedman (1977) heighten inflation leads to higher inflation because of the inconsistent monetary policy response in a higher inflationary period by monetary authorities. Most of the studies regarding the relationship between inflation and inflation uncertainty on Turkish economy supported the Friedman-Ball hypothesis. On the other hand regarding Meltzer-Cukierman hypothesis, the results are mixed.¹¹ Nas and Perry (2000) examined the Turkish economy for the interaction inflation and inflation uncertainty by using monthly consumer price Index data from the period January 1960 to march 1998. They use GARCH model to inflation data to construct a time-varying volatility of inflation as the measure of inflation uncertainty. They divided the data sample into four sub-period according different structural and policy environmental changes in the Turkish economy. They found substantial evidence of inflation uncertainty lowers inflation during the period 1980-1989. However, the results were insignificant at higher lags. During 1986 to 1998, they found that inflation uncertainty causing higher inflation, in supports of stabilizing the behavior of central banks. These results were also not significant at higher lags. Similar results were also found for the sample period of 1990s. Berumen et.al (2001) used an EGARC model for their analysis, criticizing the above simple GARCH model used by Nas and Perry (2000). They took the consumer price index (CPI) data obtained for the period January 1986 to December 2000 for their analysis. They found no evidence of inflation causing inflation uncertainty. Telatar and Telatar (2010) examined the causal relationship between inflation and inflation uncertainty during the period march 1995 December 2000. He used a more advanced time series technique as compared to the previous study of Berumen et.al (2001) and Nas and Perry (2000). He used a time varying Markov-switching heteroscedasticity model to construct the inflation volatility as a measure of inflation uncertainty along with Granger causality test to analyses the causal relationship. They decomposed the inflation uncertainty to time varying parameter and heteroscedasticity disturbance for the better understanding of the sources of uncertainty.

¹¹ See Nas and Perry (2000) ,Neyapti(2000) ,Bermunt and Metin-Ozcan et.al (2001) ,Teltar and Teltar(2003) ,Ozdemir and Fisunoglu(2006)

For the uncertainty arising from the time varying parameter, they found that inflation positively cause inflation uncertainty in support of Friedman-Ball hypothesis. The inflation arising from the unpredictable disturbance or the heteroscedastic disturbance was found to be uncorrelated with inflation in their study.

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Opiela and Jiranyakul (2010) estimated the statistical relationship between inflation and inflation uncertainty for the ASEAN-5 economies.¹³ They used a AR (p)-EGARCH (1, 1) to inflation defined by monthly percentage change consumer price Index (CPI) for each country from January 1970 to December 2007. The ASEAN-5 economies, they argued, are characterized by a lower rate of inflation as compared to other emerging market economies, but even in a low inflation regime they found a feedback relationship between inflation and its uncertainty in all five countries.

By using an asymmetric P-GARCH model Daal and Naka et.al. (2005) examined both developed and emerging market economies.¹⁴ . They found that the parameter of the P-GARCH model significant and stable for all countries, however, the parameters of asymmetric effects found to be differing across the region. For all the Latin American countries, India, UK, Egypt, and Morocco, they found that the asymmetric coefficient of P-GARCH model significant and negative, implying higher positive inflationary shock leads to high inflation uncertainty. The positive effect of inflation uncertainty on inflation is found to be significant for all the Latin American countries and all Middle East countries. The results also support five out of the seven of the G7 countries, the Latin

¹³ They examined for Indonesia, Malaysia, Philippines, Singapore and Thailand

¹⁴ The authors examined five Asian economies namely, India, Indonesia, Srilanka, Thailand, Pakistan six Latin American countries namely, Argentina, Mexico, Colombia, Venezuela, Peru four Middle East countries namely, Bahrain, Egypt, Morocco, Turkey along with G7 countries.

American countries (except for Peru). They found mixed results of the association between inflation and inflation uncertainty. For Germany, Italy and UK, among the G7 countries, the effect of inflation uncertainty of inflation found to be significant and positive in their analysis, supporting the Cukerman-Metzler hypothesis.¹⁵ Holland stabilization hypothesis is supported by three Latin American countries and for India. The positive effect of inflation uncertainty on inflation is supported in positive effects for Indonesia and two middle-east countries Bahrain and Egypt supporting Friedman-Ball hypothesis.

Empirical studies discussed above used a two-way procedure to test the relationship between inflation and inflation uncertainty. Berumenta and Dincer (2005) analyzed the interaction between inflation and inflation uncertainty for G7 countries by using a different methodology for the period 1957 to 2001. They apply the Full Information Maximum Likelihood Method with extended lags to the consumer price index data to test the possible causal relationship between inflation and its uncertainty. The full information likelihood, they argued, is better as compared to previous studies by Grier and Perry (1998) and others because, it takes a one-way procedure to test the causal relationship between inflation uncertainties rather a two-way procedure to incorporate the generated data of inflation uncertainty.¹⁶ In their study, inflation is found to cause inflation uncertainty in support of Friedman-Ball hypothesis for all the G7 economies. They found that for countries like US, Japan, Canada, UK and France, inflation uncertainty granger cause inflation in support of Meltzer-Cukierman hypothesis. Inflation uncertainty lowers inflation supporting Holland hypothesis for UK, Canada, US, and France. They also employed the previously used two-way procedure of Grier and Perry (1998) to study the interaction between inflation and inflation uncertainty. They found the similar results for the Friedman-Ball hypothesis in all G7 countries in the two-way procedure and mixed results for the other hypothesis.

¹⁵ This was supported by the study of Grier and Perry (1998) for Japan and France.

¹⁶ Peggan and Ullah(1984) also argued for using FIML method.

Thornton (2007) studied 12 emerging market economies using monthly data of inflation found higher inflation rates increases inflation uncertainty and evidence on the effects of inflation uncertainty on average inflation are mixed.¹⁷ Using the granger causality test, he examined the causal relationship between inflation and inflation uncertainty. He found a significant and positive impact of inflation on inflation uncertainty in all the 12 economies supporting the Friedman-Ball hypothesis. Holland hypothesis is supported which suggest that high inflation leads to lowering inflation uncertainty due to the stabilizing behavior of monetary authority: this hypothesis is supported by Turkey, Colombo Mexico and Israel. For countries like Korea, Hungary and Indonesia inflation uncertainty found to be lead to more inflation supporting the Meltzer-Cukierman hypothesis.

Elder (2004) examined the impact of inflation uncertainty on real economic activity by developing a new model by synthesizing the Vector Auto Regression (VAR) and multivariate generalized conditional heteroskedastic (MGARCH) model for US economy. Their results show that inflation has a harmful welfare effect. (Foot note) They demonstrated that inflation uncertainty tends to reduce about 22 basis points of economic growth over three months in the post-1982 period. They also find the negative relationship holds for the post-1982, post-1966 as well as pre-1976 samples.

Conrad and Karanasos (2004) analysed the causal relationship between inflation and inflation uncertainty for UK, Japan and The USA. They used monthly data of consumer price Index (CPI) for the period 1962–2001 to construct inflation. For their empirical analysis for construction the series of inflation uncertainty, they used a ARFIMA–FIGARCH as opposed to simple GARCH model because, the advantages of using e ARFIMA–FIGARCH model is that it properly incorporate the long memory aspect of

¹⁷ The author examined for Colombia, Hungary, India, Indonesia, Israel, Jordan, Korea, Malaysia, Mexico, South Africa, Thailand, and Turkey.

inflation and its uncertainty. The other advantage of using the ARFIMA–FIGARCH model is that, it allows for a comparison of the relative efficacy of different GARCH model in capturing inflation uncertainty. First, they found that inflation raise inflation uncertainty in all countries in supports of the argument put forwarded by Friedman and Ball. The impact of inflation uncertainty on inflation, they found, to be insignificant for USA and weak but significant for UK. So, it is ambiguous to argue that inflation will fall as a response to rise in inflation uncertainty with a more independent central bank. The Cukierman and Meltzer hypothesis is supported for the Japanese economy. Thornton (2008) use a GARCH (1, 1) model for annual inflation data of Argentinian economy a positive and significant short-run relationship between inflation and inflation uncertainty supporting Friedman hypothesis. Thornton (2005) by using a GARCH model found a positive and significant causal relationship running from monthly average inflation to inflation uncertainty in India data covering from 1957 to 2005 in support of the argument put forth by Friedman. Choudhury (2011), by using the same GARCH methodology used by Thornton for Indian economy demonstrated a feedback relationship between inflation and inflation uncertainty supporting both Friedman and Cukierman-Meltzer hypothesis.

Vale (2005) used a bivariate GARCH-in-Mean model in order to examine the positive nexus between inflation and inflation uncertainty given by Cukierman and Meltzer (1986) for Brazilian Economy. He argued that “in the last two decades Brazilian economy went through a huge inflation process and a near economic collapse. The crises brought a lot of uncertainty about the future of the economy and, supposedly, weakened the predictability of the major economic variables” (Vale, 2005). Cukierman and Meltzer’s (1986) hypothesis of a positive association between inflation and inflation uncertainty is also supported by his study. By using exponential generalized autoregressive conditional heteroskedastic (EGARCH) model Narayan et al. (2009) examine the dynamics of inflation and inflation uncertainty for the Chinese economy. Their findings consistent with the Holland (1995) hypothesis that increased inflation uncertainty lowers average inflation for the Chinese inflation dynamics are concerned.

Hasanov(2011) studied the interaction between inflation rate, economic growth rates and their interaction with their uncertainties for ten Central and Eastern European transition countries. They used monthly data of Index of Industrial Production (IIP) data and Wholesale Price index data (WPI) as a proxy for output growth and inflation. They found the evidence that, inflation uncertainty heighten inflation for countries like Bulgaria, Czech Republic Croatia, Poland, Hungary, Romania, Macedonia, and Slovakia. Further, they found that, except for Slovakia, all other countries strongly support the Friedman-Ball hypothesis. In their study, the Cukierman-Meltzer (1986) hypothesis is supported for Hungary and Macedonia, where, inflation uncertainty found to raises inflation. The "stabilizing fed" hypothesis of Holland (1995), in which inflation uncertainty reduces inflation, is supported by in the case of Bulgaria, Czech Republic, Croatia, Poland, Romania and Slovakia.

Corporal, Onorante et al. (2012) adopt a time-varying AR-GARCH model to estimate the conditional volatility of inflation as a measure of inflation uncertainty in the Euro area and investigate their linkage via a VAR framework and letting the possible impact of regime changes due to the formation of European Monetary Union (EMU) in 1999. They found that long run inflation and inflation uncertainty had declined since the formation of EMU and short-run uncertainty has stabilized. Using a sequential dummy procedure they also found evidence of a structural break with the introduction of euro area resulting in lowering long run uncertainty. Their results show that the direction of causality between inflation and inflation has been reversed and Friedman-all hypothesis empirically supported. They also argue that the ECB can lower inflation uncertainty by monetary policy aiming at lowering inflation.

Corporal and Kontonikas (2009) adopt a time-varying GARCH framework to estimate the conditional volatility of inflation in order to distinguish between short- run uncertainty and steady state uncertainty in 12 economies of European Monetary Union

(EMU).¹⁸ By analysing the link between inflation and inflation uncertainty they found that EMU had a significant and substantial relationship between inflation and inflation uncertainty. They found that the Friedman-Ball link between inflation and inflation uncertainty have become weak and distracted in some countries.

Tas (2012) using the asymmetric power GARCH (PGARCH) and GARCH methodologies examine whether the Inflation Targeting (IT) countries achieve lower inflation variability by using explicit inflation targeting monetary policy.¹⁹ He used monthly consumer price index CPI for each country and inflation rate defined by the log difference of CPI. His evidence from both individual and panel data analysis show that inflation targeting shows that IT is an important policy option to curb inflation uncertainty. Thus, they argued that countries with higher inflation uncertainty should consider for adapting inflation targeting (IT) monetary policy. He found the evidence in support of Friedman-Ball hypothesis, especially, in developing countries where level inflation leads to higher inflation variability.

Chen et.al. (2006) employed a Hamilton's (2001) flexible regression model to analyze the relationship between inflation and inflation uncertainty for Taiwan inflation data series. The merit of this approach is that, without any prior specification of the model, one can simultaneously detect linear and nonlinear relationships in the data (Chen et.al, 2006). Their results found to be consistent with Friedman hypothesis that increase in inflation uncertainty raises inflation only in positive inflation regime. They ascertained that in a negative inflation regime a fall in inflation also leading rise in inflation. For the Cukierman-Metzler's hypothesis, both linear and nonlinear inflation uncertainty affect the inflation rate. They found that the linear uncertainty has a positive association with inflation, whereas nonlinear uncertainty has a negative effect on inflation.

¹⁸ The author examined for Germany, Italy, France, Spain Portugal, Greece, Ireland, Finland, Belgium, Netherlands, Luxemburg, and Austria.

¹⁹ He examined the industrial economies namely Canada, Iceland, Norway, Sweden Switzerland and The United Kingdom. Among the emerging market economies, he examined for Brazil, Chile, Colombia, Czech Republic, Hungary, Israel, Mexico, Peru, Philippines, Poland, South Africa, South Korea and Thailand.

Using the monthly price index, from the period April 1950 to April 2010 Hasanov and Omay (2011) found that inflation uncertainty induces output growth in their study of CEE countries. Their findings show that inflation uncertainty hurts economic growth in four countries, namely Croatia, Hungary, Poland, and Romania in the line of argument forwarded by Friedman (1977) and inflation uncertainty does increase growth in Bulgaria supports the Dotsey-Sarte (2000) hypothesis. The author used a bivariate GARCH model to generate condition standard deviation of inflation as a proxy for the measure of inflation uncertainty and Granger causality test to examine the causal relationship. Ozdemer (2010) used a VARFIMA-BEKK MGARCH model to examine the relationship between inflation uncertainty and economic growth for UK. He used Toda-Yamamoto granger casualty test as opposed to simple Granger casualty test. He found strong evidence regarding the positive effect of inflation uncertainty on economic growth. Fountas (2010) studied the inflation uncertainty and the output growth nexus for industrial countries concluded that inflation uncertainty is not detrimental to economic growth.²⁰ They used a GARCH-in-Mean (GARCH-M) model supplemented by granger causality test to explore the causal interaction of inflation, inflation uncertainty and growth. They found the evidence that inflation uncertainty causes inflation in most of the cases. The Friedman-Ball hypothesis was supported by fewer countries. The impact of inflation uncertainty on inflation was found to be insignificant.

The study by Fountas and Karnasos (2007), found a mixed evidence regarding the effect of inflation uncertainty on inflation and output growth. The author used a univariate GARCH model for their analysis. Apergis (2005) using GARCH methodology empirically explores the nexus between inflation uncertainty and economic growth in a

²⁰ The authors examined the countries like Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Great Britain, Greece, Hungary, Ireland, Italy, Japan, The Netherlands, New Zealand, Norway, Portugal, Sweden, Switzerland and USA.

panel data set for OECD countries covering a period from 1969 to 1999. His analysis largely supports the Friedman and Pindyck argument in the majority of cases that is inflation uncertainty has an adverse impact on economic growth. Empirical analysis on Bangladesh economy by Paul (2013) inflation uncertainty found to be significantly explaining economic growth as opposed the hypothesis of Friedman. He used a bivariate exponential generalized autoregressive conditional heteroscedasticity in mean (EGARCH-M) model and a data set of 1967 to 2009. Vale (2005) using a bivariate generalized autoregressive conditional heteroscedasticity (GARCH-M) found no evidence that inflation uncertainty is determinate to economic growth in the Brazilian economy.

Jiranyakul and Opiela (2011) empirically explore the impact of inflation uncertainty on inflation and economic growth for Taiwan economy using the data of Consumer Price Index (CPI) and Industrial Product Index (IPI) from January 1993 to December 2008. The author used a bivariate constant conditional correlation generalized autoregressive conditional heteroskedastic CCC-GARCH (1, 1) model to the data set to generate inflation uncertainty series, supplemented by Granger causality test to find the causal inferences of inflation uncertainty. They found a negative welfare effect of inflation on economic growth. They also found that, inflation and inflation uncertainty exhibit bidirectional casualty, in support of both Friedman-Ball hypothesis and Cukierman and Meltzer (1986) hypothesis.

Using the monthly data of Consumer Price Index (CPI), Payne (2007) analyzed the Caribbean countries regarding the causal nexus of inflation and inflation uncertainty. They used ARMA-GARCH model to construct inflation uncertainty and, then by applying Granger causality he examines the generated data series. The persistence of volatility due to inflationary shocks is found to be very high in their study for Jamaica and Bahamas as compared to lower impact on the Barbados. They found the evidenced in supports of Friedman-Ball hypothesis for all the three countries. Mladenovic (2007)

studied the Serbian economy using Consumer Price Index (CPI) data from June 2001 to June 2007 about the nexus between inflation and inflation uncertainty both short horizon and long horizon. Based on the GRACH specification and Granger causality test, they found that high inflation heighten inflation uncertainty while, high uncertainty tends to reduce inflation in the long horizon.

At present in the Indian context, however, there are no exclusive studies available on the studies concentrating on the Indian economy. Drawbacks of the existing studies by Thornton (2005) and Choudhury (2011) is the application the simple symmetric GARCH model. Other available empirical studies on India are either along with emerging market economies or combined studies of a bucket of countries.

2.6 Measurement of Inflation Uncertainty in the Empirical Literature

Uncertainty is an unobservable concept and, hence, by its subjective nature, it needs a proper theoretical tool box to construct an appropriate measure of inflation uncertainty. A good measure of inflation uncertainty is crucial for further empirical analysis. Because of its nature, different models were put forwarded to measure inflation uncertainty each one of them have their own applicability and limitations. The earlier theoretical literature assumes that the differences in the standard deviation of inflation across countries are a valid measure of the differences in inflation uncertainty across countries.²¹ But this measure of inflation uncertainty faces from some important and crucial shortcomings in capturing uncertainty as it fails to distinguish between anticipated and unanticipated inflation.

Grier and Perry (1998) pointed out that, in the work of Ball or Cukierman and Meltzer (1986), uncertainty is driven by the variance of stochastic and unpredictable elements of variables. So, by the nature of the uncertainty, a measurement based on simply the difference in standard deviation may not be adequately able to capture the quantum of inflation uncertainty. Evans (1991) pointed out that, “even if the computed volatility of

²¹ See for example Blejer(1979), Prak(1979)

inflation is small or large, uncertainty about future inflation could be different. Another measure of inflation uncertainty is a cross-sectional dispersion of survey-based individual forecasts and moving standard deviation of inflation. But this measure of inflation uncertainty subjected unreliability and biasedness in the confidence interval (Bamberger, 1996).

Evan (1991) argues that, even a small increase in volatility of inflation, people will face greater uncertainty if they have little information about the stance of monetary policy. Suppose, in a case of high volatile inflation but if people were well informed about the changes in the monetary policy the associated inflation uncertainty will be low. Firstly, simple measure volatility may be misleading indicator of inflation uncertainty. Secondly, people form their expectation based on the available information set. To overcome these problems, the ARCH and GARCH models are extensively used in the empirical analysis.²²The GARCH types of models have several advantages as compared to other simple measure of variability. The ARCH and GARCH models provide the unpredictable changes in the time varying conditional variance. Further, asymmetric GARCH models are used to capture the leverage effects of conditional volatility. The other sources of volatility are the structural changes in the economy. To capture the effects of structural changes regime dependent GARCH models are used for empirical analysis as the simple-GARCH and asymmetric-GARCH models undermines these sources of inflation uncertainty.

2.7 Conclusion

This chapter brings out an archival detail of the theoretical literature as well as empirical evidence of the relationship between inflation, inflation uncertainty and economic growth. The theoretical literature and the empirical evidence regarding the relationship between inflation and inflation uncertainty and economic growth are inconclusive and ambiguous. The section 2.1 of this chapter deals with the theoretical literature. From the

²² See for example Fountas et al. (2006), Fountas and Karanasos (2007). Caporale(2004)

theoretical literatures, Okun (1971), Friedman (1976) and Ball (1992) argued for a positive relationship between inflation and inflation uncertainty due to lack of creditably of monetary authority in a response to high inflationary period. Metzler and Cukierman (1986) hypothesis suggest a positive causal relationship between inflation uncertainties to high inflation. Challenging the argument of Metzler and Cukierman (1986), Holland (1995) argued that inflation uncertainty will lead to fall in inflation. Pourgerami and Makus (1987) argue that as the economic agent spend more resources on forecasting inflation a higher inflation leads to lowering inflation uncertainty. So, from the above competing hypothesis it is inconclusive to argue a particular line of the causal relationship between inflation and inflation uncertainty. On the relationship between inflation uncertainty, Friedman (1971), Pindyck (1976) and Fisher and Modigliani (1978) argue that inflation uncertainty leads to lowering economic activity and economic growth and contrasting to the argument of Dostrey and Sarte (2000) where, a positive association between inflation and inflation uncertainty.

In the above empirical literature, the hypothesis and causal relationship are also found to be inclusive. In section 2.2 of this chapter, the existing empirical evidence regarding the causal relationship between the inflation and inflation uncertainty described in details. A details mechanism of the interaction between uncertainty, growth and inflation are described in section 2.3 of this chapter. In section 2.4, the measurement of inflation uncertainty in the empirical literature and gradual development of better and more conclusive measurement of inflation uncertainty is described. Early empirical literature was vastly hooked on the standard deviation of the inflation and relative price variability to measure inflation uncertainty. Some of the research used survey methods of inflation forecast for the analysis.²³This measurement of inflation uncertainty hardly captures the unpredictability when economic agents rely on other variable which are predictable. After the Engel (1982) seminal work on the Auto Regressive Conditional Heteroskedastic (ARCH) model and subsequent adaptation and development by *Bollerslev* (1986) work of Generalised Autoregressive Conditional Heteroskedastic (GARCH) model, the measurement of inflation uncertainty largely shifted towards the conditional time varying

²³ See for Example Ungar and Zilberfarb (1993)

variance, estimated from the GARCH family of models to measure of inflation uncertainty.

Chapter-III

Data and Methodology

3.1 Introduction

In this chapter, the data sets and underlying methodology used for the empirical analysis of the interaction of inflation, inflation uncertainty and economic growth in India are presented. In the section 3.2, the data set and methods to use inflation and economic growth is described. The inflation and growth is measured by the logarithmic differences of Wholesale P seasonally price Index (WIP) data and growth as the logarithmic differences of seasonally adjusted index of industrial production data (IIP) data. Before carrying out the empirical analysis, some preliminary properties of data are examined, in the section 3.3, the ADF, KPSS and PP unit root test are performed to examine the stationary property of the data series. These tests are described in detail in the section 3.3. The ARCH-LM test is described in details in section 3.4. Section 3.5 and 3.6 contains description of the symmetric and asymmetric GARCH models used and the granger causality test. For the stability of the parameter, Nyblom stability test is used described in section 3.7.

3.2 Data

The empirical analysis of underlying objective has been carried out by two monthly data series namely the Index of Industrial Production (IIP) and Wholesale Price Index (WPI). The monthly data of WPI and IIP are taken from EPW research foundation access through University of Hyderabad (UoH) web subscription. The empirical estimation of relationship between inflation, inflation uncertainty are carried out using IIP and WPI

from April 1971 to October 2014 yielding a sample size of 522. Inflation is measured as the point to point logarithmic difference of WPI data.

$$\pi_t = \frac{\log(WPI_{t-1})}{\log(WPI_t)} * 100 \dots \dots \dots Eq(3.1)$$

For measuring economic growth, the logarithmic difference of IIP data is used as a proxy for economic growth

$$g_t = \frac{\log(IIP_{t-1})}{\log(IIP_t)} * 100 \dots \dots \dots Eq(3.2)$$

Before calculating economic growth and inflation, all the data are seasonally adjusted by X-12-ARIMA methodology.

3.3 Unit root tests

Before estimating any models, it is essential to investigate the time series properties of time series variables such as stationary or order of integration. Several tests have been proposed to check whether a data has a unit root or series is free from long memory.

3.3.1 ADF Test

This test was proposed by Dickey and Fuller (1981) which test the null hypothesis of a unit root against the alternative hypothesis of stationary. Suppose the equation 3.3 is the inflation process where the stochastic part is represented with an $AR(P)$ process without trends.²⁴

$$\pi_t = \alpha_1\pi_{t-1} + \alpha_2\pi_{t-2} \dots \dots \dots \alpha_n\pi_{t-n} + \mu_t \dots \dots \dots (3.3)$$

$$E(\mu_t) = 0 \text{ and } E(\mu_t^2) = \sigma_\mu^2 \dots \dots \dots (3.4)$$

Where μ_t an unobservable zero is mean white noise process and time invariant variance and α are coefficient. Using the lag operator the equation 3.3 can be written as

²⁴ It can be represented with the trends.

$$\alpha(L) = (1 - \alpha_1 L - \dots - \alpha_n L^n) \dots \dots \dots (3.5)$$

$$\text{With } \alpha(L) = 1 - \alpha_1 L - \dots - \alpha_p L^p \dots \dots \dots (3.6)$$

The process is stable and stationary if

$$\alpha(z) \neq 0 \dots \dots \dots (3.7)$$

$$\alpha(z) \leq 1 \dots \dots \dots (3.8)$$

$$\text{Where, } z = (1 - \alpha_1 - \dots - \alpha_p) \dots \dots \dots (3.9)$$

The process is integrated when, $\alpha(1) = 1 - \alpha_1 - \dots - \alpha_p = 0$ is the null hypothesis against the process is stationary. Subtracting both the sides by and rearranging the terms it can be written as.

$$\Delta\pi_t = \theta\pi_{t-1} + \sum_{i=1}^{n-1} \alpha_i \Delta\pi_{t-i} + \mu_t \dots \dots \dots (3.10)$$

We can include a constant or trend in the model 3.10, where $\theta = -\alpha(1)$ and $\alpha_j = (\alpha_{j+1} \dots \dots \dots \alpha_n)$. In this model, the null hypothesis is $H_0: \theta = 0$ against the alternative hypothesis $H_1: \theta < 0$. This is the statistics of the coefficient θ from OLS estimation. The critical value are given by Fuller (1978) and Davidson and MacKinnon (1993).

3.3.2 KPSS test

Another test called KPSS test, the acronym for Kwiatkowski, Phillips, Schmidt & Shin (1992), is used where the null hypothesis is the series is stationary against the alternative that integrated of order one.

It is assumed that there no time trend in the model 3.11

$$\pi_t = z_t + x_t \dots \dots \dots (3.11)$$

$$x_t = x_{t-1} + \vartheta_t, \vartheta_t \sim iid(0, \sigma_\vartheta^2) \dots (3.12)$$

$$x_t \sim iid(0, \sigma_\vartheta^2) \dots \dots \dots (3.13)$$

Where z_t a random walk is process and x_t is a stationary process. Here the ϑ_t independently and identically distributed with mean zero and variance σ_ϑ^2 and x_t is an independently and identically distributed process. With mean zero and variance σ_x^2 . In this framework, the null hypothesis will become. Here if $\sigma_\vartheta^2 = 0$ then inflation series is composed of a constant and stationary process so; alternatively the previous hypothesis will become the null hypothesis $H_0 = \sigma_\vartheta^2 = 0$ against the alternative hypothesis $H_0 = \sigma_\vartheta^2 > 0$. The KPSS statistics is given below

$$KPSS = \frac{1}{T^2} \sum_{t=1}^T \frac{S_t^2}{\hat{\sigma}_\infty^2} \dots \dots \dots (3.14)$$

Where, $S_t = \sum_{j=1}^t \hat{w}_j$ with $\hat{w}_t = \pi_t \hat{\pi}$ and $\hat{\sigma}_\infty^2$ is an estimator of

$$\hat{\sigma}_\infty = \lim_{T \rightarrow \infty} T^{-1} \text{var} (\sum_{t=1}^T x_t) \dots \dots \dots (3.15)$$

Where $\hat{\sigma}_\infty$ is the long run variance process of the ϑ_t .

3.4 ARCH-LM test

After removing the seasonal component of the data, test for the stationary is conducted whether the series has a unit root. Confirming that the series is stationary, an ARMA models have been proposed for inflation process. The ARMA are criticized for it's a theoretical nature however, it provides the more scope to study the dynamic properties of time series data. Box-Jenkins (1976) provided the methodology to construct an appropriate ARMA model. So following the methodology of Box-Jenkins (1976) and by observing the autocorrelation and partial autocorrelation function, ARMA models are identified.

Suppose an AR (1) inflation process of inflation

$$\pi_t = \alpha_1 \pi_{t-1} + \mu_t \dots \dots \dots (3.16)$$

$$\mu_t \sim (0, \sigma^2) \dots \dots \dots (3.17)$$

$$\mu_t | \Omega_t \sim (0, \sigma_t^2) \dots \dots \dots (3.18)$$

$$\Omega_t = (\mu_{t-1}, \mu_{t-2}, \mu_{t-3} \dots \dots \dots) \dots \dots (3.19)$$

If μ_t is independent, there is no distinction between the conditional and unconditional distribution of μ_t . If the current shocks are dependent on the past shocks, then the conditional distribution of the series will be different.

The conditional distribution is given by equation 3.16. The conditional distribution is given by. The conditional distribution explains the dynamic properties error characterized by time varying heteroskedasticity.

The ARCH effect is tested by using ARCH-LM test proposed by Engel (1982). In this test, the squared of the residual is regressed with a constant and the square of the past innovation or the square of the lagged value of the residuals given in equation 3.20. Here ε_t is a white noise and μ_t^2 is the square of the residuals. The null hypothesis indicates that the presence of the ARCH effect in inflation series and the alternative hypothesis indicates that the absence of ARCH effects. The ARCH effect is an intuitive sign of the presence of persistence of volatility.

$$\mu_t^2 = \phi_0 + \phi_1 \mu_{t-1}^2 + \varepsilon_t \dots \dots \dots (3.20)$$

$$H_0: \phi_1 = 0, H_1: \phi_1 \neq 0 \dots \dots \dots (3.21)$$

3.5 Measurement of inflation uncertainty

To analyze the relationship between inflation, inflation uncertainty we need a measurement of inflation uncertainty. As inflation uncertainty not directly observable we need a reliable proxy for measuring inflation uncertainty. Earlier studies measured moving standard deviation as a measure of inflation uncertainty

3.5.1 The symmetric and asymmetric GARCH models

The GARCH time series studies that examine the link between inflation and inflation uncertainty use a variety of empirical methodology. We first used GARCH type of model of inflation to estimate inflation uncertainty used by Grier and Perry (1998).

$$\pi_t = \omega + \sum_{i=1}^n \pi_{t-i} + \varepsilon_t \dots \dots \dots (3.22)$$

$$\sigma_t = \omega + \alpha \varepsilon_{t-1}^2 + \beta \sigma_{t-1}^2 \dots \dots \dots (3.24)$$

$$\varepsilon_t \sim (0, \sigma_t^2) \dots \dots \dots (3.26)$$

The equation (3.3) is an autoregressive representation of inflation process. It can be described as a stochastic difference equation in which the current level of inflation series linearly related to the past values, plus an additive stochastic shock. The stochastic shock assumed to be zero mean and time varying conditional variance σ_t^2 . This is following is the GARCH(1,1) specification of GARCH(p, q) process where ω, α and β are parameters. The GARCH (1, 1) model gives the current time varying volatility as a linear combination of lagged volatility and lagged squared forecast error. The positivity of is ensured by the following sufficient restriction $\omega > 0, \alpha \geq 0$ and $\beta \geq 0$. If q lags of ε_{t-1}^2 and p lags of σ_{t-1}^2 are included instead of setting $p=q=1$ as above the model is said to be GARCH (p, q) model. The sum $\alpha + \beta < 1$ is ensure that the conditional variance evolve over time. It also refereed to as the persistence of conditional variance process.

The simple GARCH model cannot account for leverage effect in the model. The non-negativity constraint may lead to inadequacy in estimation. The asymmetric response can be estimated by extension to the standard GARCH models. Now, we represent below some popular frequently asymmetric GARCH models.

$$\ln \sigma_t^2 = \omega + \theta_1 \left| \frac{\varepsilon_{t-1}}{\sigma_{t-1}} \right| + \theta_2 \frac{\varepsilon_{t-1}}{\sigma_{t-1}} + \beta \ln(\sigma_{t-1}^2) \dots \dots \dots (3.27)$$

One of the most widely used model is EGARCH originally introduced by Nelson (1991), is re-expressed in Bollerslev and Mikkelsen (1996) given in equation (3.7). The logarithmic representation $\ln \sigma_t^2$ ensure that that the σ_t^2 will be positive even if the

parameter is negative hence ruled out the non-negativity constraint on the model parameter. The model allows for the asymmetric response depending on the sign of news.

Another popular model is proposed by Glosten, Jagannathan, and Runkle (1993) is known as GJR model. The generalized version of the model given below

$$\sigma_t^2 = \omega + \sum_{i=1}^q (\alpha_i \varepsilon_{t-i}^2 + \gamma_i s_{t-i} \varepsilon_{t-i}^2) + \sum_{j=1}^p \beta_j \sigma_{t-j}^2 \dots \dots \dots (3.28)$$

Where s is a dummy variable that take the value 1 when γ_i is negative and 0 when it is positive. In this model, it is assumed that the impact of ε_t^2 on the conditional variance σ_t^2 is different when ε_t is positive or negative.

Another model used for capturing the leverage effect in GARCH model known as APARCH model proposed by

$$\sigma_t^2 = \omega + \sum_{i=1}^q \alpha_i (\alpha_i |\varepsilon_{t-i}| - \gamma_i \varepsilon_{t-i})^\delta + \sum_{j=1}^p \beta_j \sigma_{t-j}^2 \dots \dots \dots (3.29)$$

In the model $\delta > 0$ and $-1 < \gamma < 1$ ($i = 1, 2, \dots, q$) .the parameter δ plays the role of Box-Cox transformation of σ_i while γ_i reflects the so-called leverage effect.

3.6 Granger causality test

We used the granger casualty test on the estimated conditional variance and inflation and growth to find out the causal relationship between them. To test the relationship between inflation uncertainties on inflation the following regression is run.

$$\pi_t = \alpha_0 + \sum_{i=1}^k \alpha_i \pi_{t-i} + \sum_{j=1}^k \beta_j h_{t-1} + \varepsilon_t \dots \dots \dots (3.30)$$

Here π_t is inflation and h_{t-1} in lagged estimated conditional variance from GARCH model. Rejection of null hypothesis $\beta_j = 0$ is that inflation uncertainty granger cause inflation. Depending up the sign of the β_j the direction of causality determined If

hypothesis $\beta_j \neq 0$ and positive, inflation uncertainty increases inflation supporting Cukierman and Meltzer (1986) and if the sign is negative then inflation uncertainty reduces inflation in support of Holland (1995) hypothesis.

Similarly, to test the relationship between inflation uncertainties to inflation the following regression is run.

$$h_t = \alpha_0 + \sum_{i=1}^k \alpha_i h_{t-1} + \sum_{j=1}^k \beta_j \pi_t + \mu_t \dots \dots \dots (3.31)$$

The rejection of null hypothesis from Eq (3.10) $\beta_j = 0$ implies inflation Granger-cause inflation uncertainty. Similarly if the sign of the coefficient β_j is positive then inflation uncertainty increases inflation supporting the Friedman-Ball hypothesis. If the sign is negative then inflation uncertainty reduces inflation supporting the argument of Pourgerami and Makus (1987), Ungar and Zilberfarb (1993).

To test the causal relationship from inflation uncertainty to economic growth, the following regression is used.

$$g_t = \alpha_0 + \sum_{i=1}^k \alpha_i g_{t-1} + \sum_{j=1}^k \beta_j h_{t-1} + \varepsilon_t \dots \dots \dots (3.32)$$

Here g_t is economic growth. The rejection of null hypothesis from $\beta_j = 0$ Eq (3.32) implies inflation uncertainty Granger-cause economic growth. If the sign of β_j is positive then inflation uncertainty increases growth argued by Dotsey and Sarte (2000) and if negative supports the argument of Friedman (1977), Fischer and Modigliani and Pindyck (1991).

3.7 Nyblom's parameter stability test

The Nyblom parameter stability test is based on the idea that, if a parameter is stable its variance must be zero over time. Consider a general linear model with n number of variable given in equation 3.33. If the error variance of the parameter is stable then the error variance of μ_t is zero $\sigma_{\mu}^2 = 0$ and if the parameter is not stable the error variance is not zero.²⁵

²⁵ See Zivot(2003) <http://faculty.washington.edu/ezivot/book/structuralchangeslides1.pdf>

$$y_t = x_t\beta + \varepsilon_t, t = 1, 2, \dots, n \dots \dots (3.33)$$

$$\beta = \beta_t = \beta_{t-1} + \mu_t \dots \dots \dots (3.34)$$

$$\mu_t \sim (0, \sigma_\mu^2) \dots \dots \dots (3.35)$$

$$i = 1, 2, \dots, K$$

$$H_0: \beta \text{ is constant} \leftrightarrow \sigma_\mu^2 = 0 \text{ for all } i \dots \dots (3.36)$$

$$H_1: \sigma_\mu > 0 \text{ for all } i$$

Chapter -IV

Inflation, Inflation Uncertainty and Growth: Some Evidence

4.1 Introduction

In chapter-2, the theoretical and empirical literature on the causal link of inflation, inflation uncertainty and growth are described in details. From the theoretical literature six possible hypothesis are derived, attributed to Friedman (1977), Okun(1971) , Ball(1992) Holland (1995) Cukierman and Meltzer (1986) Pourgerami and Makus(1987) ,Ungar and Zilberfarb (1993), Modigliani and Pindyck(1991) and Dotsey and Sarte(2000). In this chapter, the empirical analysis of those hypotheses is carried out in the Indian context by following the methodology described in the previous chapter.

4.2 Trends in inflation

The wholesale Price Index (WPI) is the main measure of inflation in India. The WPI is available for all commodities and for major groups, sub-groups and individual commodities. For policies purposes and academic discussion, the inflation based on WPI is considered as most suitable price index, even though it suffers from heavy criticism as it does not include the services sector which has the largest share of GDP of Indian economy. The historical trends in inflation are depicted in fig4.1. The fig4.2 and table 4.1 are factors attributed higher inflationary periods.

India has traditionally been a low inflation country except come occasional hike is inflation due to supply shocks and remained low throughout the period (chart 4.1).²⁶ The major spike in inflation was during 1972-1975 can be seen from the chart-4.1. The rising inflation was mainly attributed to drought and hike in the crude oil prices, large monetary expansion, and Indo-Pak war. Between the years 1971 to 1975, there was 30 month of two-digit inflation. (See from chart 4.2 and table-4.1). The highest inflation was almost reaching during 1970s 35 percent. The inflation in September the inflation was 33.33 percent. There is a spike in inflation, from the chart4.1, in between 1979to 1981. This rise in inflation was primarily driven by second oil price shock, rising global prices and agricultural drought. In February 1980, the inflation 25.23 was the highest, the lowest was -2.91 percent in May 1978. In May 1982, it was drastically declined to 0.07 percent. After the two periods the highest inflation, inflation has moderated.

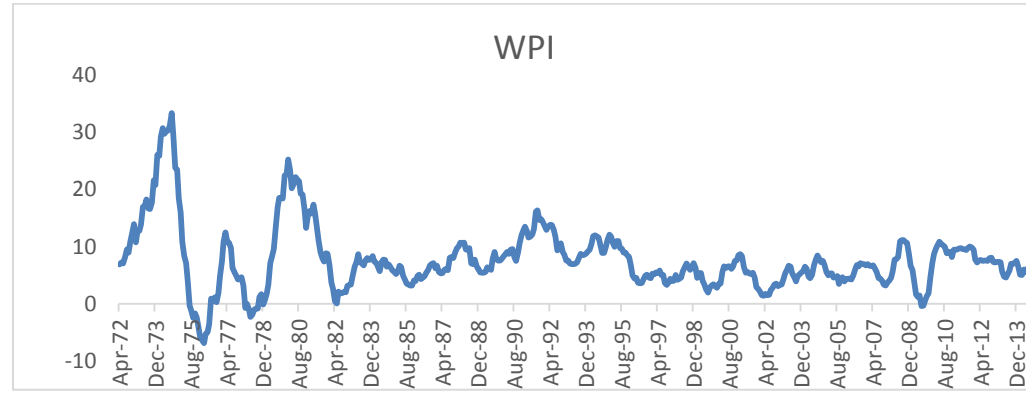
In the period 1990 to 1991 there was another surge in the inflation. During 1990 and 1991 there was 21 months of double digit inflation due to the drought, cumulative impact of a large fiscal deficit and 37 percent rupee depreciation. In September 1991, it was 16.91 percent. From 1995-96 to 1997-98, there was a reversal of trend, as reform measures began to show positive impact on prices.

There were two inflationary period 2007-2008 and 2009-2010. The High global commodity prices, large credit expansion for 3 years surge in food and fuel prices are prime drivers of inflation during those periods. In May 2008, the inflation was 11.12 percent and in May 2010 inflation was 10.88 percent. In between 2008 and 2009 there

²⁶ A good survey of trends in inflation can be found in Mohanty (2010), Gokaran (2010)

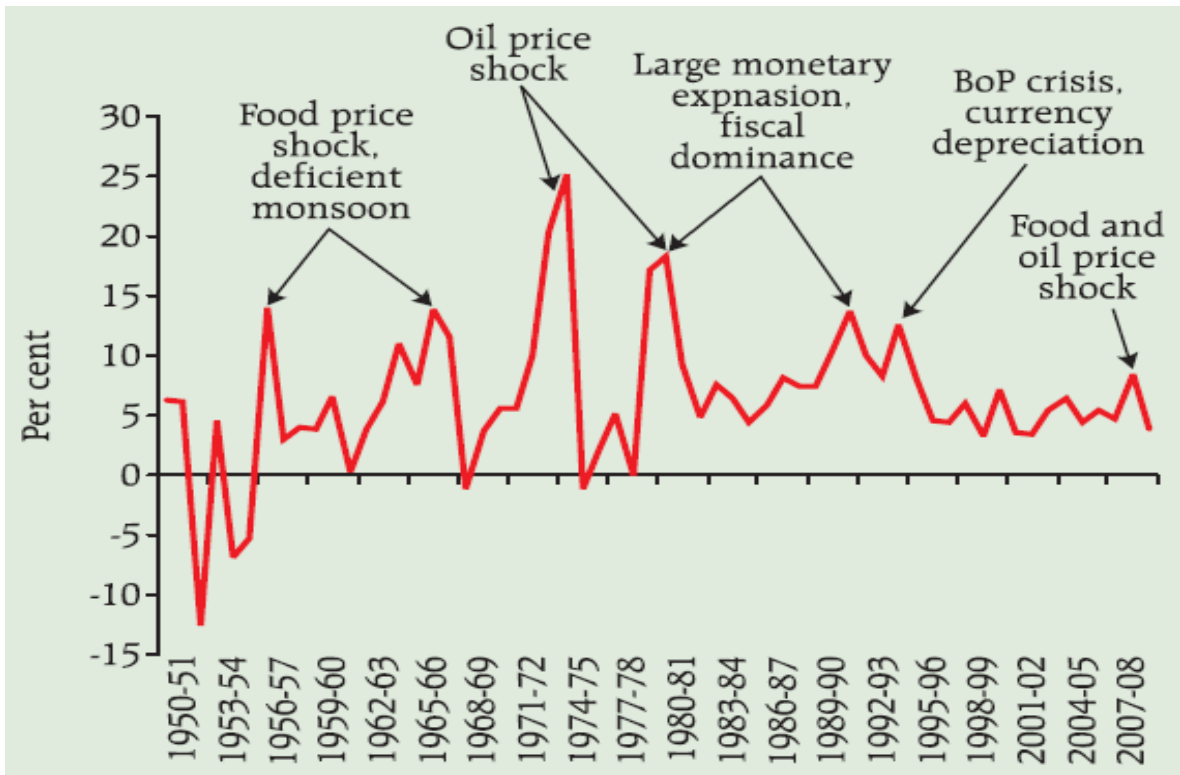
were 10 months of double-digit inflation. The volatility in inflation measured by standard deviation was highest during the 1970s and it has drastically come down after 1990s.

Chart-4.1. Year on Year increase monthly inflation (WPI)



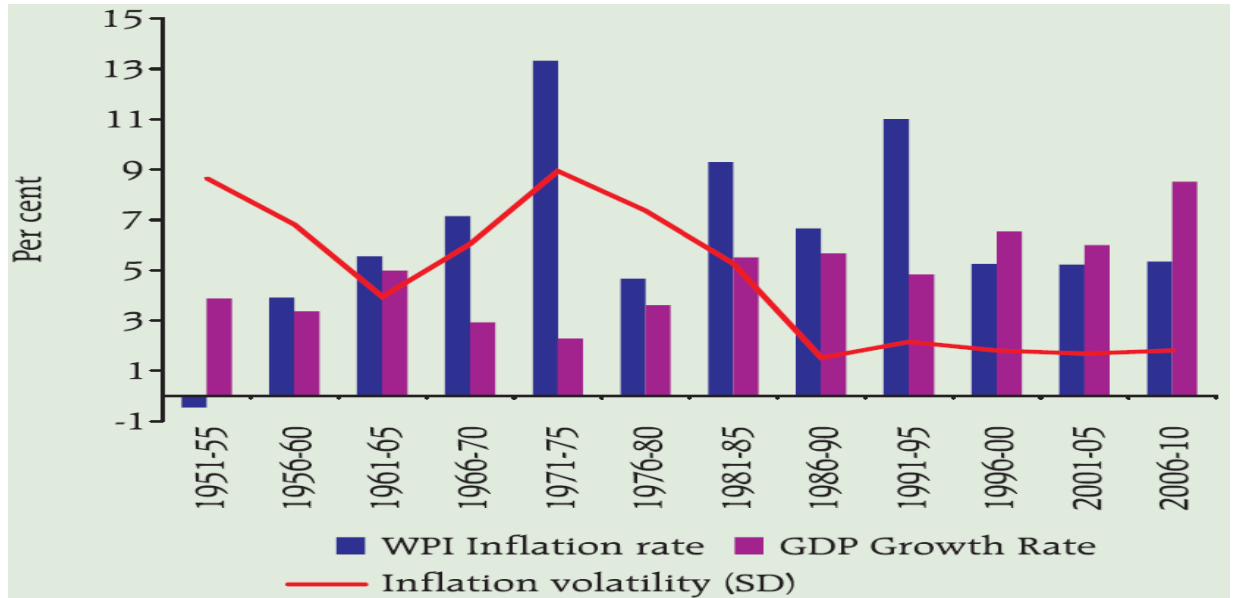
Data Source-EPW Research Foundatio3

Chart 4.2- Major Sources of inflation (WPI)



Source-Gokaran (2010)

Chart4.3-Inflation Volatility (Standard Deviation)



Source- Gokaran (2010)

Table-4.1 Periods of Double Digit Inflation

SL- No	Periods	Number of months	Causal factor
1	Oct-71 to Mar-75	30	1-Drought 2-Indo-Pak War 3-First oil price shock Higher global grain and metal 4-Prices Large Monetary Expansion even as output decelerated
2	Jun-79 to Aug-81	26	1-Drought 2-Second oil price shock 3-Global inflation
3	Nov-90 to Jul-92	21	1-Drought 2-Increase in the prices of 3-administered items and excise 4-duties 5-Cumulative impact of large fiscal deficit

			6-37 per cent rupee depreciation in 1991-92
4	Mar-94 to May-95	15	1-Substantial hike in administered prices 2-Shortfalls in the production of cash crops 3-High fiscal deficit 4-Large monetary expansion
5	Jun-08 to Oct-08	5	1-High global commodity prices 2- Large credit expansion for 3 years
6	Mar-10 to Jul-10	5	1-Drought 2-Administered price increases 3-Reversal of global commodity 4-prices after fall during global crisis

Source-Mohanty (2010).

4.3. Measurement of growth and inflation

For the measurement of inflation and economic growth, the point to point logarithmic difference of wholesale Price Index (WPI) and Index of Industrial Production (IIP) data are used. Both the data series are collected from Economic and Political Weekly (EPW) research foundation. The period of data chosen from April 1976 to October 2014 yielding a data set of 522 observations.²⁷ The seasonally adjusted data then used for the calculation of inflation and growth series by following methods²⁸

The point to point logarithmic difference of monthly WPI data is taken as proxy for inflation, calculated by equation 3.4

²⁷ All the data are changed to 1993-1994 base year. Before calculating the inflation and economic growth, all the data sets are seasonally adjusted by using X12-ARIMA methods

$$\pi_t = \frac{\log(WPI_{t-1})}{\log(WPI_t)} * 100 \dots \dots \dots Eq(4.1)$$

The economic growth is calculated by same formula, the point to point logarithmic difference of IIP data given in the equation

$$g_t = \frac{\log(IIP_{t-1})}{\log(IIP_t)} * 100 \dots \dots \dots Eq(4.2)$$

4.4 Descriptive statistics

We first examine the descriptive statistics of inflation measured from the equation 4.1 reported in table 4.2. The mean value is found to be 0.2579; skewness 0.81 and 3.4620 kurtoses implies that the distribution is skewed towards rights The Jarque-Bara statistics shows that the series is normally distribution with mean 0.2579. The powerful statistics of Anderson-Darling test reject the null hypothesis that series is normally distributed. The chart-4.5 also confirmed that the data is skewed toward the right.

The Ljung-Box Q statistics of raw and squared data autocorrelation with lags 5214.982(0.0000) and 20 are highly significant implies the presence of higher order autocorrelation and the possible presence of ARCH effect. The estimated inflation data are represented in chart 4.4. There is no visual evidence of serial correlation in the inflation, but there is evidence of serial correlation in the amplitude of the inflation. That is, volatility appears to cluster: Large changes tend to be followed by large changes and small by small, of either sign.

Chart-4.4 Estimated inflation series.

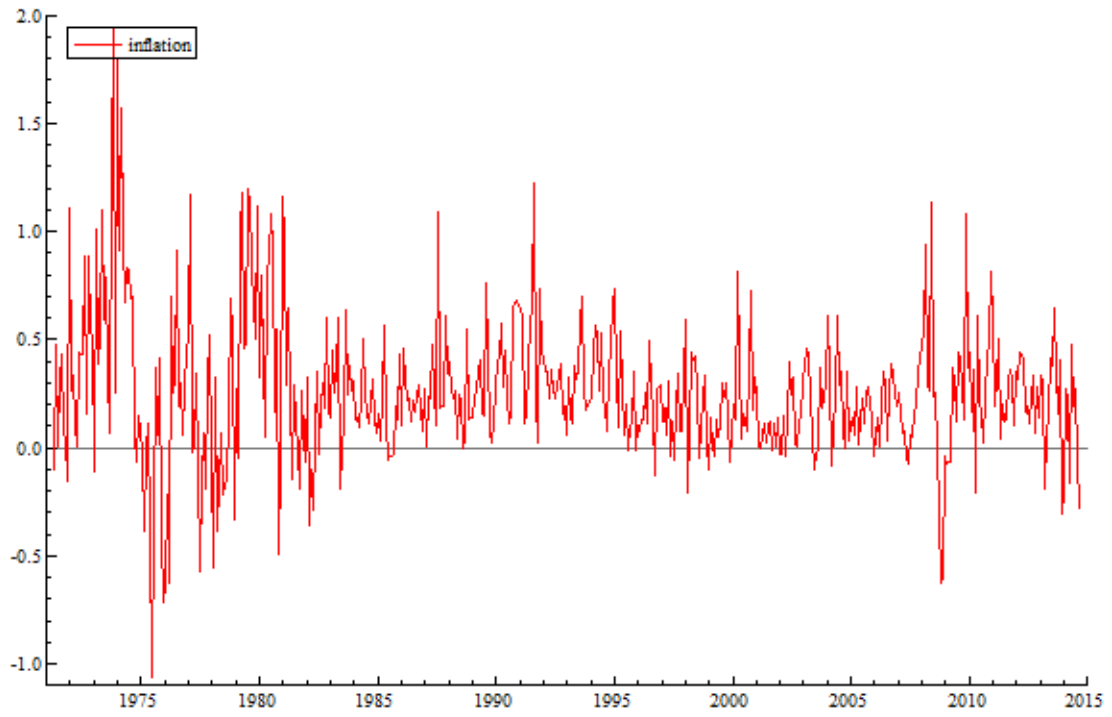


Chart-4.5-Frequency Distribution of estimated inflation series

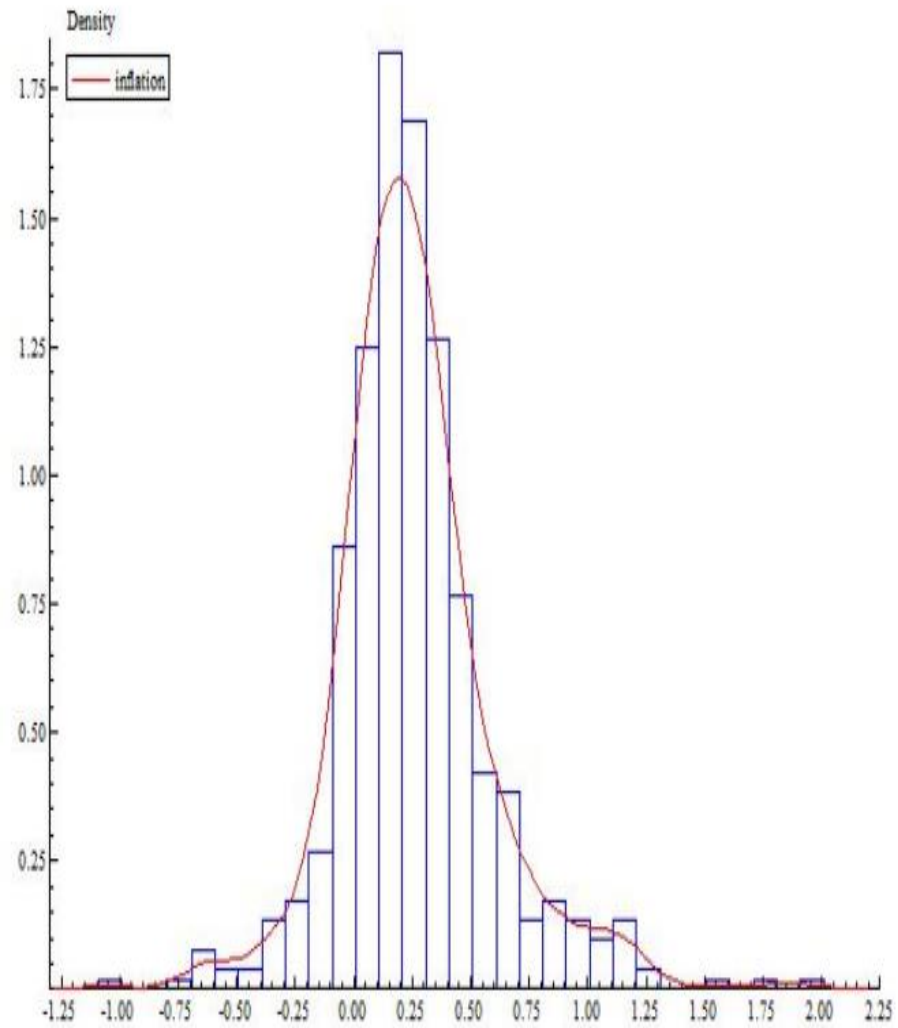


Table-4.2.Summary statistics

Mean	0.2579
Skewness	0.81238(3.1548e-014)
Excess Kurtosis	3.4620 (4.4814e-059)
Jarque-Bera	317.49(1.1405e-069)
Anderson-Darling	9.7786 (1.1405e-069)
Q(5)	214.982(0.0000000)
Q(20)	311.740(0.0000000)
Q*2(5)	251.515(0.0000000)
Q*2(20)	376.936(0.0000000)

Note: p-value in the parenthesis

4.5 Unit root test

Before the continuation of the estimation of the models stationarity of the inflation data is examined. The Augmented Dickey-Fuller test (ADF), Kwiatkowski-Phillips-Schmidt-Shin (KPSS) and unit root used to analyses the presence of unit root in monthly inflation data. The test statics are reported in Table4.3. The ADF test statistics reject the null hypothesis that the series has unit root at 1 percent level of significance. Whereas the KPSS test is based on the null hypothesis of stationary of the data found to be non-rejection of the null hypothesis at 1% level of significance. Based on the all the test statistics we can confirm that the series is stationary with 1 percent level of significance.

Table-4.3 Unit root Test statistics

Tests	Coefficient Of Inflation
ADF	--10.3927*(0.0000)
KPSS	0.0718443*

Note: The lag length KPSS test is selected according to new-west bandwidth method, *p*-value is indicated in the parenthesis, *indicates significance at 1% level. The MacKinnon critical value for ADF test at 1 percent level is -3.4323.

4.6 ARCH-LM Test

Next ARCH-LM test proposed by Engel (1982) is used to check the possible ARCH effect present in the inflation data which is a prerequisite to proceed further to estimate GARCH family of models. The ARCH-LM test statics are reported in Table4.4.

Table-4.4 LM-ARCH Test statistics

LAGS	F-STAT	P-VALUE
ARCH 1-2: F(2,3263)	55.685	0.00000
ARCH 1-5: F(5,3257)	28.065	0.00000

ARCH 1-10: (10,3247)	15.012	0.00000
----------------------	--------	---------

The F statistics of the ARCH-LM test indicate that the null hypothesis of no ARCH effect is rejected at 1% level of significance at different lag length chosen. Based on the Ljung-Box Q statistics of Table-4.2 and ARCH-LM statistics of Table-4.4 we can confirm that the variance of the inflation series is heteroskedastic and present of ARCH effect in the data. This indicates that the variance of the inflation is heteroscedastic and exhibit time-varying volatility, the variance of the current error term of inflation is correlated with the variance of the previous error terms of inflation. So, the results confirm that ARCH and GARCH type model may provide an efficient estimate of the data.

4.7 Estimation of symmetric and asymmetric GARCH models.

Subsequently, the estimated symmetric and asymmetric GARCH models are reported in Table 4.2 and 4.3. The parameters of symmetric GARCH models reported in the table are significant at conventional level of significance adequately capture the volatility presence in the inflation data. The sum of the coefficient that is $(\alpha + \beta)$ is greater than 0.9 and less than one in all the estimated symmetric models. This signifies the high level of volatility clustering present in the data set and mean reverting character.

The parameters of asymmetric coefficient of asymmetric GARCH model found to be statistically not significant i.e. $\Theta(1)$ and $\Theta(2)$ of ARMA(1,0)-EGARCH(1,1) model coefficient of ARMA(1,1)-GJR(1,1), δ coefficient of ARMA(1,1)-APARCH(1,1) found to be not significant.²⁹ The results of asymmetric GARCH models show that there is no asymmetric response in the volatility of the monthly inflation data. As the models are not significant, we checked the post estimation diagnostic test only for the symmetric GARCH models estimated. The residual based conditional diagnostic (RBD) test for all the three models are reported in table 4.7.

²⁹ For a good survey of these models see Bauwens et al.(2012)

The test results suggest that, non-rejection of the null hypothesis of a correct specification of the estimated models at higher lags. However, for model like ARMA(1,2)-GARCH(1,1) and ARMA(1,0)-GARCH(1,1), the RBD statistics show that, there exist significant correlation in the error term at the lag 5 signaling incorrect specification of the model.³⁰ According to the information criteria, the symmetric models are ranked and presented in table 4.8. The least the value of information criteria the better is the model because we are trying to minimize the loss of information. The ARMA(1,1)-GARCH(1,1) model ranked first followed by ARMA(1,1)-GARCH(1,1), ARMA(1,0)-GARCH(1,1).

Table-4.5 Parameters of Symmetric GARCH models

Models→ Parameters	ARMA(1,2) GARCH(1,1)	ARMA(1,0) GARCH(1,1)	ARMA(1,1) GARCH(1,1)
$\alpha(0)$	0.002536 (0.0101)	0.002548 (0.0781)	0.002815 (0.1392)
$\alpha(1)$	0.107068 (0.0249)	0.105137 (0.0137)	0.118206 (0.0625)
$\beta(1)$	0.862125 (0.0000)	0.864715 (0.0000)	0.849176 (0.0000)
Distribution	GAUSS	GAUSS	GAUSS

³⁰ For the methodology of residual based diagnostic of conditional heteroskedastic see Tse(2002).

Note: All the models are tested assuming different type of distribution

(Student-t, GED) and no significant difference was found in the parameters

Table 4.6 Parameters of Asymmetric GARCH Models.

Models→ Parameters	ARMA(1,1) EGARCH(1,1)	ARMA(1,1) GJR(1,1)	ARMA(1,1) APARCH(2,1)
$\alpha(0)$	-2.530357 (0.0000)	0.001994 (0.2007)	0.023398 (0.4563)
$\alpha(1)$	-0.267533 (0.5446)	0.107004 (0.0000)	0.256395 (0.0011)
$\beta(1)$	0.954442 (0.0000)	0.875302 (0.0000)	0.107925 (0.3709)
$\beta(2)$			0.627628 (0.0000)
$\Theta(1)$	0.010979 (0.8712)		
$\Theta(2)$	0.363736 (0.0499)		
γ		-0.005240 (0.9133)	-0.100854 (0.5852)
δ			0.842189 (0.4134)
Distribution	GAUSS	GAUSS	GAUSS

Note: All the models are tested assuming different type of distribution

(Student-t, GED) and no significant difference was found in the parameters

Table-4.7 Residual Based Digenetic Test statistics

MODEL	RBD(2)	RBD(5)	RBD(10)	DISTRIBUTION
ARMA(1,2) GARCH(1,1)	1.07026 (0.5855921)	28.5187 (0.0000288)	0.781600 (0.9999451)	GAUSS
ARMA(1,0) GARCH(1,1)	1.19424 (0.5503947)	14.4219 (0.0131402)	-16.5745 (1.0000000)	GAUSS
ARMA(1,1) GARCH(1,1)	1.26515 (0.5312212)	1.52946 (0.9096456)	4.68720 (0.9110703)	GAUSS

Table 4.8 Ranking of Models According To Information Criteria

MODEL	AKAIKE	SHIBATA	HANNAN- QUINN	SCHWARZ	RANK
ARMA(1,2) GARCH(1,1)	0.188285	0.187931	0.210683	0.245464	1
ARMA(1,0) GARCH(1,1)	0.203053	0.202871	0.243895	0.219051	3
ARMA(1,1) GARCH(1,1)	0.190379	0.190118	0.209577	0.239390	2

4.8 Estimation of inflation uncertainty

For estimating inflation uncertainty we used the conditional variance of ARMA (1, 2)-GARCH (1, 1) model because the model has significant parameters and correct specification according to RBD test and ranked first among the symmetric GARCH models according to information criteria.. For the constancy of the parameters of the ARMA (1, 2)-GARCH (1, 1) model over time, Nyblom(1989) stability test is being used.

4.8.1 Nyblom's stability test

The Nyblom's test is based on the idea that, if a model is correctly specified, the variances of the parameters are zero over time. From table 4.9 the Nyblom's test statistics are significant at 1 percent level so the parameters are stable over the period of time concerned. Now we estimated the conditional variance as a proxy for the inflation uncertainty.³¹

Table- 4.9 Statistics of Nyblom's stability test.

Parameters	Statistics
$\alpha(0)$	0.11406*
$\alpha(1)$	0.37121*
$\beta(1)$	0.33170*

Note: * signifies significance at 1 percent level. Asymptotic 1% critical value for individual Statistics is 0.75

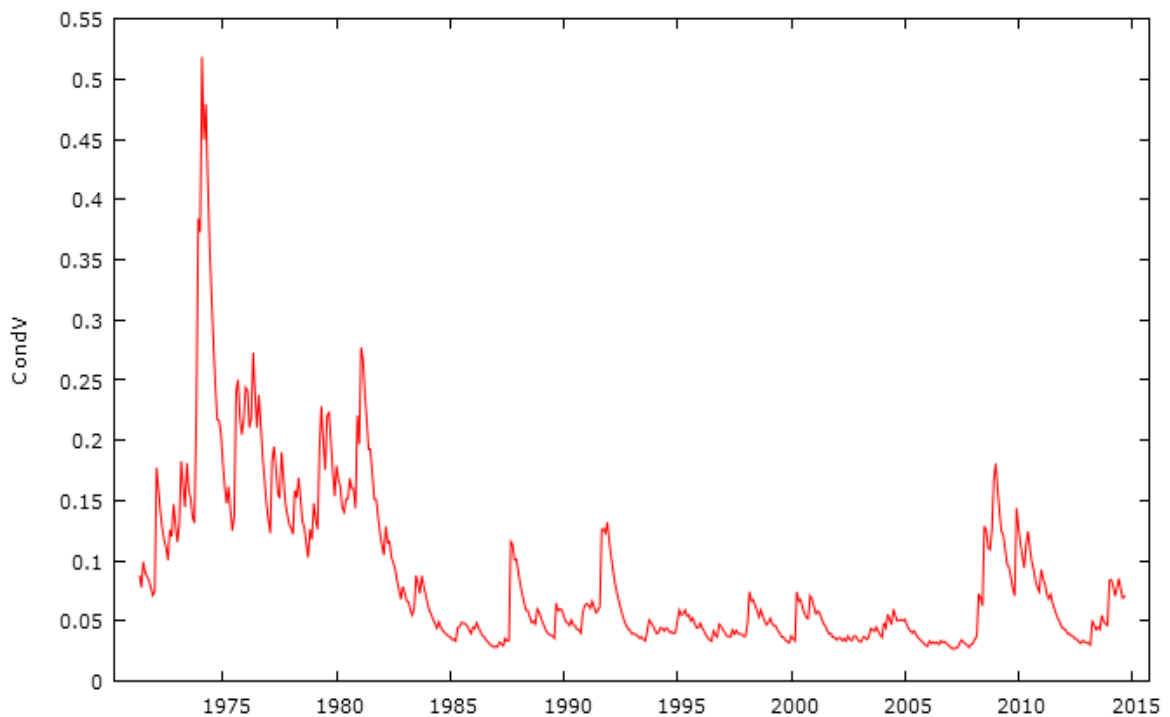
4.8.2 Stylized facts of inflation uncertainty

The conditional volatility, as a measure of inflation uncertainty, obtained from ARMA (1, 1)-GARCH (1, 1) models is presented in the chart 4.6. In the chart 4.7, the estimated inflation volatility and inflation are simultaneously presented to visually examine their co-movement. Similarly, in the chart 4.8, the inflation volatility and economic growth are simultaneously depicted to make a visual inference of their relationship.

³¹ See for more detail methodology Nyblom(1989)

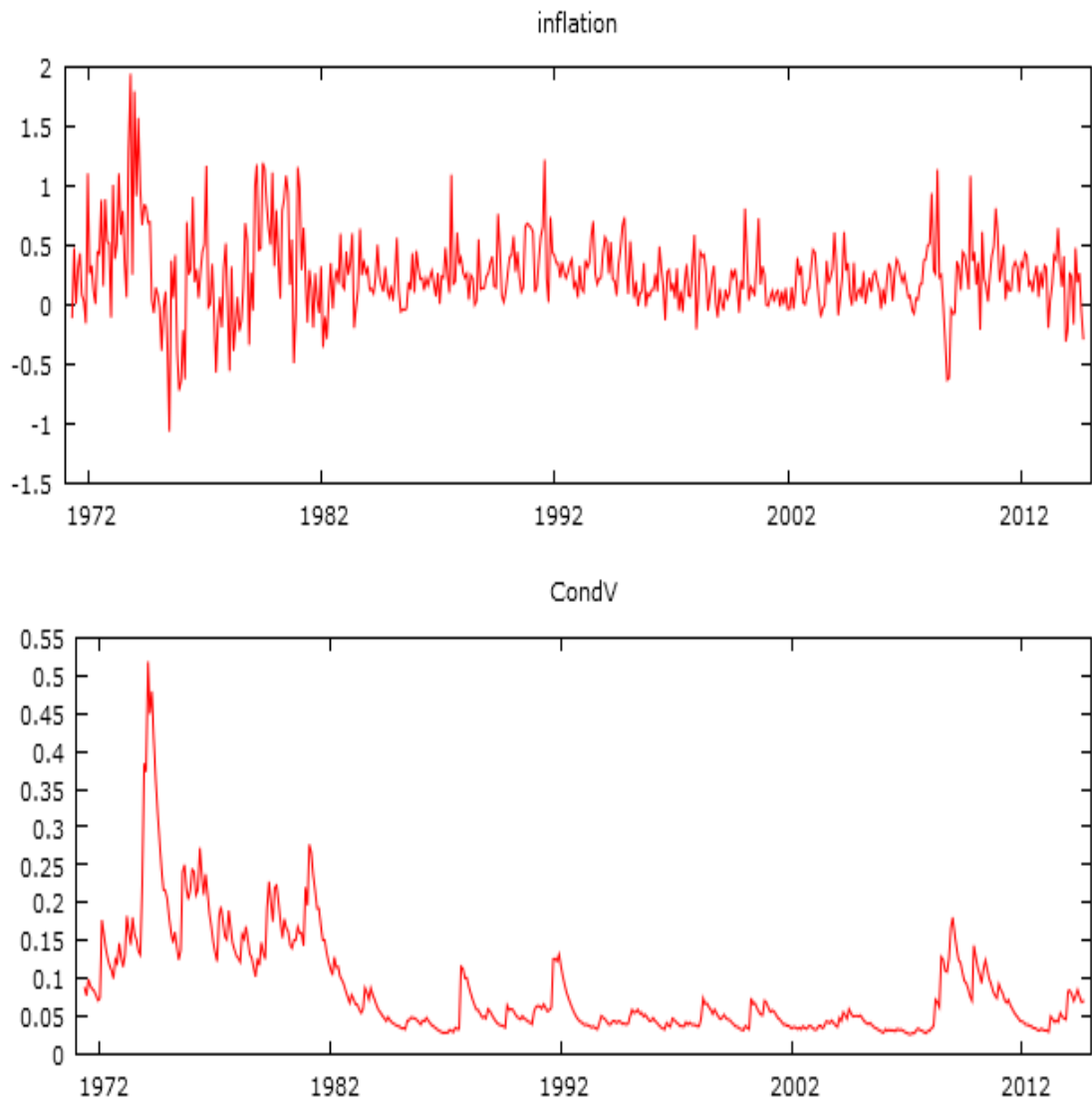
The chart 4.7 shows that higher inflation volatility is associated with high inflation uncertainty. The higher volatility is in the periods 1970s and 1980s coinciding the periods of double-digit inflation during the periods of the oil crisis. In the recent periods, as the chart 4.6 suggest that inflation uncertainty has raised somewhere between 2008-2010, and in this periods there was 10 month of double-digit inflation³². The chart4.7 shows that higher inflation is associated with high inflation uncertainty, but the char4.8 shows no such pattern of relationship between growth and inflation uncertainty.

Chart-4.6-Conditional Variance as a measure of Inflation uncertainty



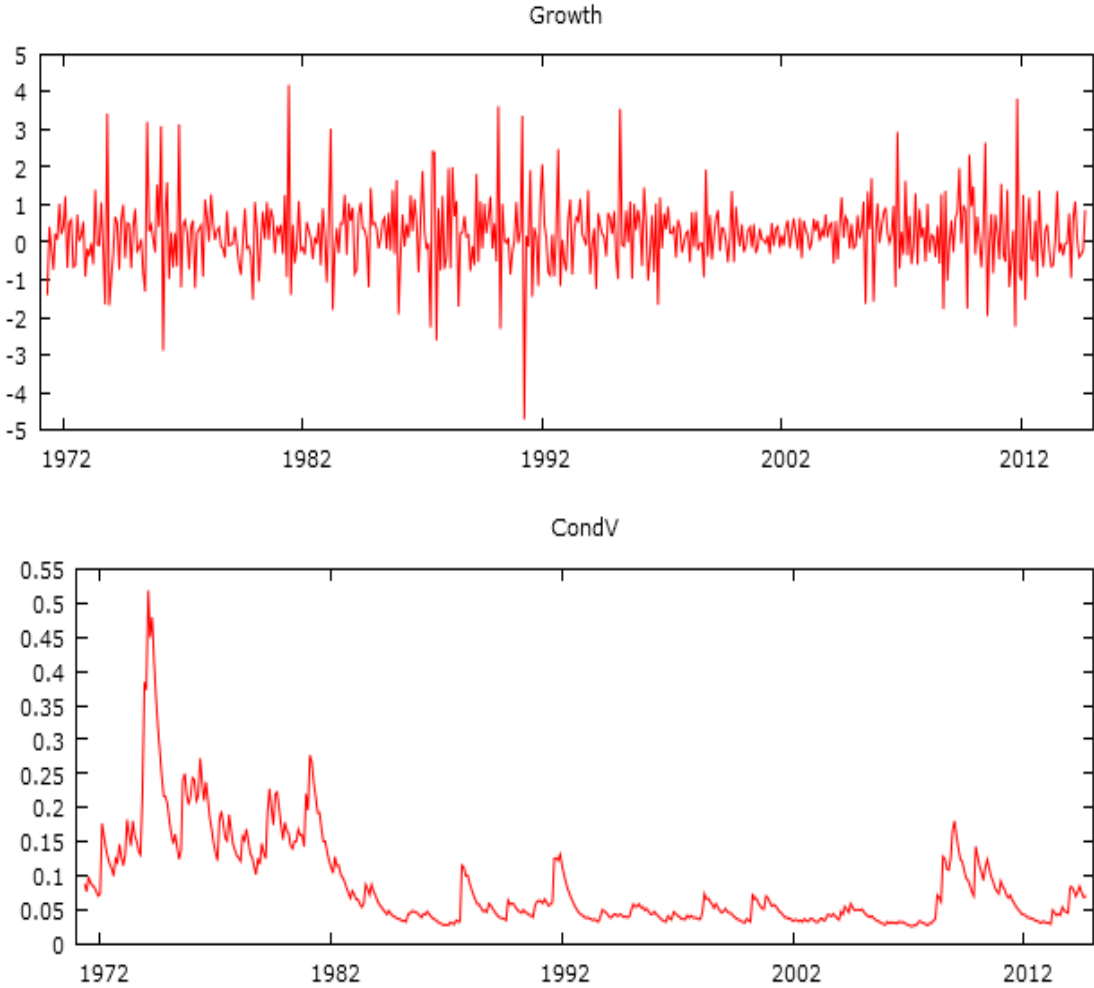
³² (Refer to Table-4.1).

Chart4.7-Inflation and Conditional Variance³³



³³ The conditional time varying variance is used as a proxy for inflation uncertainty.

Chart-4.8 Growth and Conditional Variance³⁴



³⁴ The time varying conditional variance used as a proxy for inflation uncertainty.

4.9 Granger causality test

Following Grier and Perry (1998), bivariate granger causality test is used to empirically

Lags	F-statistics	Direction of causality	P-value
2	88.354	(+)	0.000
<u>3</u>	85.204	(+)	0.000
4	86.375	(+)	0.000

analyses nexus between inflation, inflation uncertainty and economic growth. The test statistics of Granger causality test of the relationship between inflation, inflation uncertainty and economic growth are presented in table 4.10, 4.11 to Table 4.12. Depending upon the sign of the parameter the direction of causality is determined.³⁵

Table 4.10-Inflation does not granger cause inflation uncertainty

Note: The underlined lag length is chosen according to AIC criteria

³⁵ The Granger causality test is described in chapter-III. The test are performed by equation 3.1, 3.2 and 3.3 from the chapter-III

Table 4.11- Inflation uncertainty does not granger cause inflation

Note: The underline lag length chosen according to AIC criteria

Table 4.12-Inflation uncertainty does not granger cause economic growth

Lags	F-statistics	Direction of causality	P-value
2	6.4463	(+)	0.040
<u>3</u>	6.9825	(+)	0.108
4	7.586	(+)	0.179

Note: The underlined lag length chosen according to AIC criteria

From the table 4.10 the null hypothesis that the inflation does not cause inflation rejected at lags 2, 3 and 4. The results found to be consistent with the hypothesis of Friedman and Ball that the higher inflation leads to higher inflation uncertainty. Similarly, the null hypothesis inflation uncertainty does not granger cause inflation was rejected at lag 2, 3 and 4 supporting Cukierman-Meltzer hypothesis from table 4.11. The test statistics from

Lags	F statistics	Direction of causality	P-value
2	5.9839	(+)	0.050
<u>3</u>	8.4082	(+)	0.038
4	9.15	(+)	0.057

the table 4.12 suggest that inflation uncertainty doesn't Granger-cause economic growth at lag 3 and 4. The Cukierman-Meltzer and Friedman-Ball hypothesis simultaneously holds in India. The opportunistic nature of the central bank that is more emphasis on economic growth rather than inflation is confirmed.

The results obtained from these studies are consistent with the overwhelming majority of the studies that support the Friedman-Ball hypothesis, for example, Grier and Perry (1998) found that inflation significantly raises inflation uncertainty in all G7 countries. The results are also consistent with evidence obtained by Fountas and Karanasos (2007) for the US economy and all the G7 countries except Germany. The result is also consistent with the previous studies by Choudhury (2011), and Thornton (2007) on the Indian economy, where they found a bidirectional relationship between inflation and inflation uncertainty exist. The results also consistent with the study of Fountas(2001), Kontanikas(2004) and Karanasos(2005) study on UK economies. Thornton (2005) found support for the Friedman-Ball hypothesis for Argentina. Grier and Perry (1998) found no asymmetric effect in six countries of the G7 economies. Thornton (2005) studies on the 12 emerging markets support the Cukierman and Meltzer hypothesis for Korea, Israel, Hungary and Indonesia.

4.10 Conclusion

This chapter conducts an empirical exercise of the relationship between inflation, inflation uncertainty and economic growth. The estimates of inflation and economic growth are based on monthly data of Indian Wholesale Price Index (WPI) and index of industrial production (IIP) adjusted for seasonal variation from April 1971 to September 2014 yielding a sample size of 520 observations. Here inflation and economic growth are calculated by the logarithmic differences percentage change of monthly WPI and IIP. This study also has advantages over previous studies relating to the Indian Economy by adding the recent data set. The summary statistics of Inflation that are obtained from the log of the monthly growth in the Index Wholesale Price Index (WPI) are examined in this chapter. The inflation data found to be skewed towards the right. Before carrying out the empirical analysis, time-series properties of the data are examined. The monthly inflation series found to be stationary from a set of unit root tests employed for the analysis. ARCH-LM test from the table suggests a high degree of ARCH effect presence in the data. After concluding that the data has a high degree of ARCH effect, the both asymmetric and symmetric GARCH family models are estimated. The asymmetric GARCH models found to be insignificant in explaining the volatility in inflation. After the estimation, Residual

based heteroskedastic (RBD) diagnostic test is employed for the diagnostic of the effectiveness of symmetric GARCH model in explaining the conditional time varying variability in the inflation. From the symmetric GARCH models, ARMA (1, 2)-GARCH (1, 1) model is chosen to for the subsequent analysis. The stability of the parameter of the ARMA (1, 2)-GARCH (1, 1) is tested using Nyblom parameter stability test and the parameters are found to be stable. The time-varying conditional variance obtained from the ARMA (1, 2)-GARCH (1, 1) model, is considered as the proxy for the measure of inflation uncertainty. The granger causality test is then performed to test the relationship between inflation, economic growth and inflation uncertainty. The results from the Granger causality test show that there exist bidirectional causality between inflation and inflation uncertainty and no significant relationship between inflation uncertainty and economic growth.

Chapter-V

Summary and Findings

5.1 Introduction

Price stability has been the prime objective of monetary policy framework all over the world. It is a common belief that low and stable inflation improves the functioning of the markets with effective allocation of resources. Monetary policy that ensures low and stable inflation over time, contributes to long-run economic growth and financial stability. There are plenty of studies that provide arguments in favor of moderate inflation rates benefiting growth as well as against it. However, in recent times there is a line of research which focuses not only on the relationship between inflation and growth but also on the relationship with their uncertainties. First, the theoretical literature postulated different direction of link between inflation, inflation uncertainty and economic growth. Several theories and argument have been proposed to study the relationship between these variables.

Okun (1971) initiated the argument that the inflation variability can lead to heightened inflation. Friedman (1977), in his Nobel lecture provided an intuitive argument regarding the positive association between inflation and inflation uncertainty. The Friedman argument was theoretically examined in a game theoretic framework by Ball (1992) where the response of policymakers during higher inflationary periods leads to heightened inflation uncertainty.

On the contrary to the Friedman-Ball hypothesis, Meltzer (1986) and Cukierman (1992) argued that central bank may create more inflation surprise during a period of high inflation uncertainty for welfare gain. Holland (1995) argued that during higher inflationary period monetary authority responds by contractionary monetary policy aiming at reducing inflation and associated welfare costs. Pourgerami and Makus(1987),Ungar and Zilberfarb (1993) argued that, during higher inflationary environment, agents may spend more resources for inflation forecast to reduce inflation uncertainty.

Besides the relationship between inflation and inflation uncertainty, some literature examined the impact of inflation uncertainty on economic growth. Friedman (1977) draws an argument that inflation uncertainty can lead inefficient allocation of resources and hinders real economic activity. Again, Fischer and Modigliani(1978) and Pindyck(1991) argued that high inflation uncertainty can make long-term contract uncertain and reduces potential return on investment leads to lower economic growth. In contrast to this argument, Dotsey and Sarte (2000) argued that, a higher inflation uncertainty triggered by increases monetary growth can lead to increase growth via investment pulled through precautionary savings.

From this theoretical literature six hypothesis have been derived on the relationship between inflation, inflation uncertainty and economic growth. This present study examined the above hypothesis in Indian context. To examine the above hypothesis, the monthly series of wholesale price index (WPI) and index of industrial production (IIP) data are used for empirical analysis. The monthly increase in WPI and IIP are taken as a proxy for inflation and economic growth. The data used for empirical analysis are collected from EPW research foundation.

In chapter-2 a detail description of methodologies used for empirical analysis are described in details. The Autoregressive Conditional Heteroskedasticity (ARCH) models of Engle (1982) and Generalized Autoregressive Conditional Heteroskedasticity models of Bollerslev (GARCH) are used for the estimation of inflation uncertainty. Asymmetric GARCH models are also tested for possible presence of leverage effect in inflation volatility. To examine the causal relationship between inflation and inflation uncertainty, Granger causality test has been used.

5.2 Major findings

The empirical analysis from Chapter-IV shows that, inflation series is not normally distributed but the series is stationary at level. The ARCH-LM test reveals that, the past innovation in the inflation series is associated with current innovation. Further the evidence suggest that the symmetric GARCH model have the competitive edge in explaining the time varying volatility as compare to asymmetric GARCH models. The coefficient of asymmetric GARCH that meant to capture leverage effects is funds to be insignificant. So, symmetric GARCH models are chosen for the estimation of inflation uncertainty. The conditional time varying variance obtained from the symmetric GARCH is taken as proxy for inflation uncertainty.

The results from the Granger causality test suggest that inflation positively ‘granger causes’ inflation uncertainty. This argument suggests the evidence of Friedman-Ball hypothesis. The Granger causality results report a feedback relationship between inflation and inflation uncertainty. As the Granger causality running both ways, the Friedman-Ball and Cukierman-Meltzer hypotheses simultaneously hold in India. This results consistent with previously found evidence by Choudhry (2011), and Thornton (2005). No significant relationship is found regarding the causal link from inflation uncertainty to economic growth.

The positive link between higher inflation and inflation uncertainty may create suspicion regarding the monetary policy to eases higher inflation, hence; the goal should be to minimize the marginal effect of inflation on inflation uncertainty. This can be done by quick policy response to higher inflation by building confidence among economic agents regarding the policy objectives so that they can rationalize and anchor inflation expectation. The RBI should formulate specific policy objective to reduce inflation uncertainty by reducing inflation. This study does not argue for moving to explicit inflation targeting for which a more comprehensive study is necessary to look at whether environment for moving to such a kind of policy is in place. However, the empirical studies by Tas(2012) on inflation targeting countries and Kontanikas (2004) studied on UK economy concluded that, the inflation targeting countries have significantly lower inflation variances after inflation targeting.

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