Monetary Policy, Uncertainty, Output and Inflation in India

By

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DECLARATION

I **MD ZULQUAR NAIN** hereby declare that the research embodied in the present thesis entitled **"Monetary Policy, Uncertainty, Output and Inflation in India"** is an original research work carried out by me under the supervision of **Prof. Bandi Kamaiah**, **School of Economics** for the award of **Doctor of Philosophy** from **University of Hyderabad**.

I declare to the best of my knowledge that no part of this thesis is earlier submitted for the award of any research degree or diploma in full or partial fulfilment in any other University.

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This is to certify that the thesis entitled **"Monetary Policy, Uncertainty, Output and Inflation in India"** submitted by **MD ZULQUAR NAIN** bearing **Regd.No: 11SEPH01** in partial fulfilment of the requirements for award of **Doctor of Philosophy** in the **School of Economics** is bonafide work carried out by him under my supervision and guidance.

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1 | Introduction

1.1 Introduction

Given the broad corpus of work on fundamental determinants of long run growth of both developed and developing countries, uncertainty has also been considered to influence the growth dynamics. Due to the interrelationship between growth and inflation, the effect of uncertainty has not remained confined to the growth only, but the inflationary tendencies in an economy are also affected by it. Economists and policy makers have always shown their concerns about the issue of uncertainty and its associated direct or indirect macroeconomic ramifications. Even the pioneers of economic science like Alfred Marshall and Keynes were anxious about the issue of uncertainty. In the words of Alfred Marshall "although men have the power to purchase, they may not choose to use it. For when confidence has been shaken by failures, capital cannot be got to start new companies or extend old ones. Projects for new railways meet with no favour, ships lie idle and there are no orders for new ships . . . The chief cause of this evil is want of confidence"[1]. Similarly, according to Keynes, 'it is the animal spirit which has most powerful influence on investment'[2].

Conventionally, capital stock, population and technical know-how were considered to be the underlying determinants of growth (Solow, 1956). However,

[1] (Marshall, 1879, P.150-157)
[2] (Keynes, 1936a)

the lack of empirical support for convergence among different countries within this framework led a search for other factors driving the growth performance of economies. The genesis of uncertainty as an important factor to influence economic behaviour started with the works of Arrow (1962) and Romer (1986), who highlighted the significance of knowledge and associated spill over effects to explain the phenomenon of non-convergence. They attributed the issue of non-convergence to the problem of risk, the magnitude of which varies across countries. Since investment in knowledge is possibly affected by risk and therefore the importance of uncertainty got recognized (Asteriou and Price, 2005).

The new growth theory puts an appreciable emphasis on the positive role of investment in the growth process (Romer, 1986; Romer, 1987; Lucas, 1988). However, investments being affected by the element of uncertainty, the subsequent theoretical developments have elucidated the appreciable importance of later in carrying out the investment decisions (Dixit and Pindyck, 1994). The irreversible nature of investment, the uncertain future costs and benefits of investment project and flexibility about the timing of investment may have an appreciable influence on the investment behaviour. Regarding its ambiguous impact on the level of investment, the influence of uncertainty on the overall macroeconomic performance is of substantial importance and therefore an empirical exercise to point out the role of uncertainty is highly warranted.

The earlier studies documented the indirect impact of uncertainty on economic growth by scrutinizing the uncertainty and private investment nexus. However, the literature in recent times has undergone a shift towards an examination of the direct nexus among uncertainty, economic growth and inflation. The concept of uncertainty associated with Knight (1921) is inability of people to forecast the likelihood of events happening in future. A closely related concept is risk which refers to a known probability distribution over a set of events (Castelnuovo, Lim, and Pellegrino, 2017). Though, theoretically these two concepts are different but hard to differentiate empirically or in the data analysis(Castelnuovo, Lim, and Pellegrino, 2017). To the extent of literature, the term uncertainty includes both uncertainty (Knight's definition) and risk. Moreover, there is no perfect measure of uncertainty and a range of proxies like volatility of stock market, gross domestic product (GDP) or inflation has been used (Bloom, 2014). One reason to use the volatility is unavailability of perfect measure of uncertainty. Another fact is that more the series is volatile more difficult to forecast, an integral component of Knight's (1921) definition of uncertainty. However, in theoretical and empirical literature macroeconomic uncertainty has been broadly categorised into nominal (inflation) and real(output) uncertainty.

This has led to the development of lively debates like inflation uncertainty, economic growth and inflation nexus; output volatility, output growth and inflation nexus, effectiveness and predictability of monetary and fiscal policy transmission, exchange rate volatility and overall macroeconomic performance.

On this direction, following Friedman (1977), there has been considerable interest to understand inflation-output dynamics and their uncertainties, thus producing conflicting theoretical propositions. Friedman (1977) proposed a two-part hypothesis to explain the real effect of inflation. In the first part, he argued that more inflation leads to more inflation uncertainty, while the second part suggests that inflation uncertainty has a deleterious impact on growth by affecting price mechanism as an instrument of efficient resource allocation. Contrary to Friedman's arguments, Cukierman and Meltzer (1986) and Cukierman (1992) asserted that higher inflation uncertainty leads to inflationary pressures in the economy. Subsequently, in contrast to Cukierman and Meltzer (1986) and Cukierman (1992), Holland (1995) argued that higher inflation uncertainty combats the issue of inflation. This view is generally known as "stabilizing Fed hypothesis". The argument basically relies on the assumption that the chief concern of the central bank is to ensure a stable price level. Hence, when the economy is plagued with higher inflation uncertainty, a contractionary policy stance by the central bank would be imperative.

Similarly, an inconclusive theoretical debate about the effect of output uncertainty on output growth and inflation is reported in the literature. Diverse theoretical explanations have been provided for the effect of output uncertainty on output growth, but no unanimity about the direction of such effect is confirmed. Initially, the proponents of business cycle models assume that output uncertainty and output growth are neutrally related to each other since the determinants of the two variables are different altogether. The proponents of neutrality assertion assume that output growth is determined by real factors such as technological change whereas output fluctuations on the other hand are the outcome of price misperceptions. Subsequently, a number of theories advocate the possibility of a positive effect of output uncertainty on output growth. The explanation for the positive effect may be found in the idea of 'creative destruction' proposed by Schumpeter (1942). Schumpeter argued that fluctuations in output during recessionary period, leads to appreciable spending on research which ultimately pave the way for economic growth. Scholars like Pindyck (1991) argued for the existence of a negative effect of output uncertainty on output growth due to irreversibility of investment at firm level caused by output uncertainty. Likewise, Devereux (1989), through the Baro-Gordon framework and by adding a stochastic element to money growth, argued that output uncertainty leads to inflation in the economy. However, through the combination of Cukierman-Meltzer hypothesis and Taylor effect, it has been argued that the effect of output uncertainty on inflation is negative. From the above, it is clear that there is no general consensus regarding the impact of uncertainty on the overall macroeconomic performance.

Further, a sustainable growth path coupled with low and stable inflation rate has been recognized as the twin goals of macroeconomic policy all across the globe. Any divergence from these goals has been considered to be costly for the overall economy (Barro, 1996b). For the achievement of above stated goals, a considerable debate about the relative effectiveness of different macroeconomic policies such as fiscal and monetary policies has originated and lead to controversial analogies. However, a broad consensus about the relative efficacy of monetary policy is reported (Sen and Kaya, 2015; Andersen and Jordan, 1968; Batten and Hafer, 1983; Senbet, 2011; Havi and Enu, 2014). In fact in recent decades monetary policy has emerged as the most popular and effective stabilization tool for macroeconomy. However, the effectiveness of monetary policy also came under scrutiny due to the presence of heightened uncertainty. Brainard (1967) has argued for general policy ineffectiveness in presence of uncertainty. Recently, the global financial crisis (GFC) of 2007-08 and its impact on world economies followed by the seminal work of Bloom (2009) has rejuvenated the debate of the in/effectiveness of monetary policy in presence of uncertainty.

In addition,due to increased integration over the years, macroeconomic policy makers have analysed and documented the dynamics of globalisation and inflation. Put it in another way, openness has now been considered among one of the determinants of inflation, including those of conventional determinants like output gap, inflation and output volatility, money supply growth, fiscal deficit and so on. However, there is no unanimity of views among economists and policy makers about the effect of openness on inflation. Romer (1993) and Lane (1997) maintained that openness has negative effect on inflation whereas the proponents of cost push hypothesis suggest suggest a positive link between the two variables (Evans, 2007; Rajagopal, 2007). However, previous empirical studies indicate that the relationship might be conditional on the state of the economy.

In this backdrop, the present study attempts to examine the validity of the above discussed theoretical issues in Indian context. First, we examine the effect of nominal and real uncertainty on output growth and inflation. Second, role of uncertainty on the effectiveness of monetary policy. Finally, the relationship between openness and inflation.

1.2 Objectives of the study

The broad objectives of the study are as follows

i) To examine the effect of nominal and real uncertainty on output growth and inflation and their spill over effect.

i) To examine the nature of growth and inflation uncertainty on inflation and growth.

i) To examine the monetary policy effectiveness during high and low uncertainty regimes.

i) To examine the asymmetric impact of openness on inflation.

1.3 Scope and relevance of the study

The importance of carrying out the empirical exercise is reflected by conviction of the economists and policy makers across the world, that sustainable growth and low and stable inflation should constitute two fundamental policy objectives. Understanding the relationship between output growth, inflation and their uncertainties is important because the decisions of households, firms and policy makers are highly influenced by the level and stability of output growth, inflation.

Though, the relationship among output growth, inflation and their uncertainties has been examined at length. However, a lack of consensus about the effects of inflation and output uncertainty on the rates of inflation and output growth is documented. The empirical findings are sensitive to various factors including the sample period, model specification and the proxies for inflation and output uncertainty. Interestingly, findings are conflicting for the same group of countries with same data sample, when uncertainties are measured with different methods. Earlier studies have used either the variance of variables or dispersion of survey forecasts of individual forecasts as a measure of inflation and output uncertainty.

However, both these measures have the limitations. Uncertainty proxies generated from survey data may not capture the true level of uncertainty and may also contain sizeable measurement errors. Whereas, standard deviation or moving standard deviation as measure of uncertainty gives equal weightage to all past observations and thereby gives rise to substantial serial correlation in the summary measure. This leads to overstating of economic uncertainty. Later on, with the introduction of ARCH approach, most of the recent empirical studies have used the conditional variance of the ARCH (or GARCH) process of inflation and output to measure uncertainties. However, GARCH models also has come under scrutiny due to ignorance of the possibility of asymmetric impacts of positive and negative shocks on inflation and output.

In Indian context there are only few studies, which have examined the relationship between inflation, output growth and their uncertainties (Thornton, 2006; Chowdhury, 2014a; Balaji, Durai, and Ramachandran, 2016). They find mixed evidence. However, none of the above study has examined simultaneously the effects of nominal and real uncertainty on output and inflation. Moreover, these studies have ignored the issue of asymmetric effects.

Unlike the previous literature, the presents study takes account of such caveats and contributes to the existing literature in following ways. First, we examine the effect of both inflation (nominal) uncertainty and output growth (real) uncertainty on inflation and output growth by using the simultaneous approach which is considered to be more efficient compared to the two-step approach. Second, we also incorporated asymmetric and spill over effects to take account of the issues raised by Brunner and Hess (1993).

As noted above uncertainty not only affects output-inflation dynamics, but also hinders the effectiveness of stabilisation policies(Brainard, 1967). Given the fact that in recent decades monetary policy has emerged as the most popular and effective stabilization tool for macroeconomy(Sen and Kaya, 2015; Andersen and

Jordan, 1968; Batten and Hafer, 1983; Senbet, 2011; Havi and Enu, 2014), it becomes becomes imperative to examine the role of uncertainty in monetary policy effectiveness. Moreover, the global financial crisis (GFC) of 2007-08 and its impact on world economies followed by the seminal work of Bloom (2009) has rejuvenated the debate of the in/effectiveness of monetary policy in the presence of uncertainty. To our knowledge, there is no study has examined the role of uncertainty on effectiveness of monetary policy in Indian context. In this backdrop, the present study also examines the role of uncertainty in monetary policy effectiveness.

Moreover, due to increased integration over the years, evidence of flattened Phillips curve has been witnessed. The flattened Philips curve has the implication that inflation in open economies is less affected by domestic demand conditions and more by the changes abroad. This warrants for an investigation to look beyond conventional understanding of inflationary forces. However, there is lack of consensus about the effect of openness on the inflation and indicate that the relationship might be conditional on the state of the economy Romer (1993) and Lane (1997) (Evans, 2007; Rajagopal, 2007). Although openness-inflation nexus has been examined in Indian context, but all of them are based on the restrictive assumption of symmetry which can be misleading (Granger and Yoon, 2002). In this context, present study seeks to examine the relationship between inflation and openness by taking account of the asymmetric aspect of the relationship.

1.4 Data and Methodology

In order to empirically examine the issues chosen for the present study, we have used different variables, sample period, frequency and methodology for each empirical chapters. The detailed descriptions of variables and justification for sample period and methodology has been discussed in each empirical chapters.

1.5 Organisation of the study

The thesis consists of five chapters including three empirical chapters. Each of the three empirical chapter is complete in its structure. The present chapter gives an overview of different issues examined in the present study. In addition, the objectives, scope and relevance and limitations of the study.

Chapter 2 empirically examines the effects of nominal and real uncertainty on output growth and inflation. More specifically, this chapter attempts to answer the following questions. Firstly, does inflation uncertainty raise or lower the inflation? Second, does growth uncertainty retards or promotes growth? Third, what is the nature of growth and inflation uncertainty on inflation and growth? Finally, does growth and inflation respond symmetrically to negative and positive changes of uncertainty shocks?

Chapter 3 attempts to examine the impact of uncertainty on monetary policy effectiveness. More specifically we examine how different is the effect of monetary policy within high and low uncertainty regimes in India.

Chapter 4 examines the relationship between inflation and openness, popularly known in literature as "Romer Hypothesis". The chapter seeks to test the validity of this hypothesis in the Indian context by taking account of the asymmetric aspect of the relationship between the two variables.

Chapter 5 summarizes the main findings of the study.

1.6 Limitations

i) In chapter 2 and chapter 3, use of index of industrial production as the proxy for output due to non-availability of gross domestic product data at monthly frequency, which may limit the validity of the findings.

i) In chapter 2 and chapter 4 assumption of constant relation over the sample period may limit the validity of the findings.

2 | Inflation, Output growth, and nominal and real uncertainty: An asymmetric GARCH approach

2.1 Introduction

There are plethora of both theoretical and empirical studies examining the relationship between inflation and output growth. While, Bernanke (2011) argues that a low and stable inflation contributes long-run economic growth, Tobin (1965) argues that an increasing inflation raises economic growth by increasing current savings and investment. In contrast of the above two theoretical propositions, Sidrauski (1967) postulates a neutral effect. In 1990s number of empirical studies (See Barro, 1996a; Bruno and Easterly, 1996; Fischer, 1993, among others) have found that, the relationship between inflation and growth varies with the level of rate of interest. The relationship between inflation and growth is negative and significant if the rate of inflation exceeds a threshold level. Though, there is no consensus about the level of such threshold. Recently, Chu et al. (2017) and Arawatari, Hori, and Mino (2018) have given theoretical explanation of such relationship between inflation and growth. Chu et al. (2017), using Schumpeterian growth model with endogenous entry of heterogeneous firms showed that, there exist inverted-U relationship between inflation and growth, which depends on the entry cost of firms. Arawatari, Hori, and Mino (2018) within the framework of R&D based endogenous growth model suggest that the relationship between inflation and growth is non-linear. The strength of negative relationship between inflation and growth depends on heterogeneous ability of the economy and rate of inflation. The direction and the impact of inflation on growth is theoretically ambiguous (Orphanides and Solow, 1990) and the issue is not yet settled. Though, empirical studies have reached a broad consensus that the relationship between inflation and growth is not significant when the rate of inflation is relatively low.

However, in recent times, research studies have focussed not only on the relationship between inflation and output growth, but also on their associated uncertainties. These are broadly categorised as nominal uncertainty(inflation volatility) and real uncertainty(output volatility) and grouped as macroeconomic uncertainty.[1]

After the seminal noble lecture by Friedman (1977), the effect of inflation variability/uncertainty on growth and inflation along with inflation has attracted a lot of theoretical as well empirical investigations[2]. There are contradictory theoretical arguments and mixed empirical evidences about the effect of inflation uncertainty on growth as well on inflation, though positively skewed towards the negative effect of uncertainty on growth and so is the effect of output uncertainty on output and inflation. Inflation and inflation uncertainty may inhibit economic growth as the price mechanism becomes less effective instrument for an efficient

[1]In strict sense, volatility and uncertainty are two different notions, volatility measures fluctuations in a variable and uncertainty measures unpredictability of fluctuations. However, due to lack of realistic measure of unpredictability, in literature both are used as same concept. Moreover, volatility of growth rate/inflation rate, output/inflation variability, fluctuations in output/inflation are used as an identical terms in the literature.In addition to it, growth rate and output also has been used interchangeably in the literature.

[2]Though, the relation between inflation variability and inflation may traced back to Okun (1971)

allocation of resources and thereby affecting growth (Friedman, 1977; Payne, 2008). Further, an unpredictable future inflation increases the welfare cost of inflation and is major source of the cost (Dotsey and Ireland, 1996).[3] The cost of inflation and inflation uncertainty for a developing country like India is more compared to developed countries (Chowdhury, 2014a) as it hurts more to the people at lower income starta. Furthermore, a high and sustainable growth is a must for a developing countries to eradicate poverty, illiteracy or other social issues, in general lifting the standard of living of the people. Based on these observations, across the globe, a low and stable inflation and high and sustainable growth, have been two of prominent policy objectives of the policy makers.

One of the most remarkable event, since early 1980s, of industrialised and developing countries alike, has been the immense improvement in macroeconomic performance (Fountas, Karanasos, and Kim, 2006). Over the years, variability of both inflation and output growth have declined (Cecchetti and Krause, 2001) and both inflation and output growth have become more stable (Fountas, Karanasos, and Kim, 2006). India's growth and inflation performance broadly exhibit a similar trend (Chowdhury, 2014a).[4]. There have been repeated episodes of high and variable inflation, during much of the 1970s and 1980s, but since the 1990s, average inflation showed a sharp decline (Chowdhury, 2014a)[5] A similar trend has been witnessed for output growth. As observed by Rodrik and Subramanian (2004), economic growth rate increased to 3.8 percent in per capita terms during 1980-2000 from a meagre

[3]For a detailed discussion on the welfare cost of inflation, may refer Lucas (2001), Friedman (1977),Fischer and Modigliani (1978), Levi and Makin (1980), Hughes (1982) among others

[4]For more on the growth trajectory one may refer Mohan (2008), Bosworth, Collins, and Virmani (2007),Rodrik and Subramanian (2004)

[5]Inflation accelerated from an annual average of 1.9 percent during 1950s to 10.3 percent in 1970s, but dropped to 7.4 percent in 1980s and 5.4 percent during 2000-2010 Chowdhury (2014a). Moreover, Mohanty (2010), showed that volatility as well average inflation has reduced overtime and in recent decades have been on downward trend.

rate of growth of 1.7 percent during 1950-1980. The acceleration in growth continued thereafter steadily with some ups and downs in between (Balakrishnan, Das, and Parameswaran, 2017).

Indian economy since 2010-11, has also registered a robust growth despite a persistent high inflation. This observation along with what has been mentioned above raise a number of interesting questions, about the relationship among output growth, inflation and their uncertainty. First, does reduction in inflation uncertainty affect inflation as predicted by Holland (1995), Cukierman and Meltzer (1986) and Cukierman (1992)? Second, does the reduction in inflation uncertainty have favourable effect on growth? A number of theoretical explanation of such a relationship has been given such as by Friedman (1977), Pindyck (1991) and Dotsey and Sarte (2000). Third, does the output growth(real) uncertainty affect inflation and output growth? There exist theoretical expositions about the effect of real uncertainty on output growth and inflation such as proposed by Black (1987), Pindyck (1991), Devereux (1989) among others.[6]. In this backdrop, in the present chapter an attempt is made to examine the empirical relationship among output growth, inflation, and their uncertainties. The basic motivation has been to examine the possible effect of nominal and real uncertainty on output growth and inflation. More specifically, an attempt is made to answer the following questions.

- Does inflation uncertainty raise or lower the inflation?
- Does growth uncertainty inhibits or promote growth?
- What is the nature of growth and inflation uncertainty on inflation and growth?

[6]A description of these are given in Section 2.2

- Do growth and inflation respond symmetrically to negative and positive change?

Our exercise will also provide empirical relevance of the theories proposed to explain the dynamic nexus among these variables in an emerging economy like India. These theories often contradict about the possible effect of the real and nominal uncertainty on growth and inflation. For example, While, Friedman (1977) and Pindyck (1991) suggested that inflation uncertainty hurts growth, but Dotsey and Sarte (2000) predict otherwise. Similarly while Cukierman and Meltzer (1986) and Cukierman (1992) have argued a positive effect of inflation uncertainty on inflation in contrast to a negative effect by Holland (1995).

There have been similar contradictory theoretical propositions about the effect of growth uncertainty on inflation and output growth. Black (1987) argue that output uncertainty has positive effect on output growth, whereas, Pindyck's(1991) hypothesis predicts a negative effect. Devereux (1989) has argued that a high growth uncertainty raises inflation and in contrast to it, through Taylor effect(1979) and Cukierman and Meltzer (1986) hypothesis, the effect is predicted to be negative.

Earlier works have used survey based uncertainty measures and standard deviation or moving standard deviation as measure of uncertainty to examine the effect of uncertainties on inflation and growth[7]. However, both these measures have limitations. The survey based approach of uncertainty may not capture the true level of uncertainty. (See Caglayan, Kocaaslan, and Mouratidis (2016), Grier and Perry (2000) among others)[8]. Whereas, standard deviation or moving standard deviation as measure of uncertainty gives equal weightage to all past observations

[7]See Holland (1993) and Golob (1993) for the studies using these measures

[8]A detailed discussion on the use of survey based measure of uncertainty may be found in Zarnowitz and Lambros (1987), Bound, Brown, and Mathiowetz (2001)

and thereby gives rise to substantial serial correlation in the summary measure (Caglayan, Kocaaslan, and Mouratidis, 2016). Moreover, as Grier and Perry (2000) argue that these measures, do not capture the true economic uncertainty.

However, after the introduction of ARCH approach, the conditional variance of the ARCH(or GARCH) process of macroeconomic series has been used to measure uncertainty in the macroeconomic literature (Fountas, Karanasos, and Kim, 2006; Caglayan, Kocaaslan, and Mouratidis, 2016).[9]. The GARCH measure of uncertainty is considered to be superior to the survey based measure and standard or moving standard deviations as it estimates the unpredictable innovations in a variable, which corresponds well to the concept of uncertainty (Grier and Perry, 2000).[10]. There are two approaches while employing the ARCH/GARCH models to examine the effects of uncertainty of inflation and growth on the level of these two variables. These approaches are (i) a two-step approach (ii) simultaneous approach. In the two-step approach, the first step is to measure uncertainty of the variables using ARCH/GARCH models. In the second step, generally, concept of causality is used to examine the relationships. Whereas, the simultaneous approach allows simultaneous estimation of the conditional variances, a measure of uncertainty, and the mean equations for the variable under consideration, to examine the relationships. The two-step approach has been criticised as it may result in biased coefficients and standard error estimates on account of wrongly measured uncertainty (Caglayan, Kocaaslan, and Mouratidis, 2016). Furthermore, Pagan (1984) also showed that the simultaneous approach is more efficient than two-step approach, when generated regressors are used.[11].

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[9]Some studies have aslo used variants of stochastic volatility model

[10]See Grier and Perry (2000) for detail discussion on this.

[11]The survey based and the standard deviation based are also criticised on this ground as it has

Recently, there have been many studies employing GARCH techniques to examine the relationship between inflation, growth and their uncertainties. However, most of the studies focus almost exclusively on the empirical relationship: i) inflation and inflation uncertainty ii) inflation, growth and inflation uncertainty iii) output growth and output growth uncertainty. Furthermore, GARCH models also have come under scrutiny due to it's symmetric response to the negative and positive shocks of same magnitude. It is now widely accepted that a positive(negative) shock in inflation(output) is more likely to have more impact than a negative(positive) shock of equal magnitude (Brunner and Hess, 1993; Joyce, 1995). Unlike the previous literature, in this chapter, we attempt to examine the effect of inflation(nominal) uncertainty on inflation and growth and of output growth (real) uncertainty on output growth and inflation, using a simultaneous approach. Following Grier et al. (2004), we examine the relationship between the variables of interest by employing bivariate VARMA-GARCH-in-Mean model, which also allow to incorporate the asymmetric as well spillover effects. The present study contributes to scarce literature existing exclusively for Indian economy as previously India has been included with other economies. Further, we examine the effect of both inflation(nominal) uncertainty and output growth (real) uncertainty on inflation and output growth by using the simultaneous approach which is considered to be more efficient compared with the two-step approach[12]. In addition, we also incorporate asymmetric and spillover effects. Finally, policy implications of the results are also discussed in detail. The remaining chapter is as follows: section 2.2 presents various theoretical discourses explaining the relationship among inflation, output growth

to follow a two-step approach to examine the relationship

[12]Previous studies for India have used two-step approach and to the best of our knowledge no Indian studies have used simultaneous approach

and their uncertainties. A brief review of empirical literature is given in section 2.3. Section 2.4 mentions the methodological approach employed for empirical analysis. Section 2.5 analyse the results, followed by conclusion in section 2.7.

2.2 Theoretical Discourse

There have been considerable efforts by macroeconomists to understand the impact of economic uncertainty (nominal and real) on macroeconomy specifically on output growth and inflation[13]. Following Friedman (1977), there has been considerable interest to understand the effect of inflation and its uncertainty on output growth, producing conflicting theoretical propositions.

Inflation Uncertainty and Output Growth

Friedman (1977) proposed a two-part hypothesis to explain the real effect of inflation. In the first he argued that more inflation leads to more inflation uncertainty as monetary authority may respond in an unpredictable manner leading to more nominal uncertainty about future inflation.[14] The second part of the Friedman's (1977) hypothesis suggests that inflation uncertainty hurts growth. It is argued that inflation uncertainty affects the effectiveness of price mechanism as an instrument for an efficient allocation of resources, thereby inhibiting growth. Further, it has been argued that increased inflation uncertainty may also raise unemployment through its effect on optimal contract length and the degree of wage indexation(Grier and Perry, 2000). Further, there are theoretical proposition which

[13] Recent study by Bloom (2009) has renewed the interest of the researcher and policy makers alike

[14] Ball (1992) showed that a high inflation raises uncertainty as there will be increased uncertainty about the stabilization policy response from the monetary authority, through a formal model.

have shown the detrimental effect of inflation uncertainty on growth, through the investment channel (See Pindyck, 1991; Blackburn and Pelloni, 2004). Pindyck (1991) using the concept of investment irreversibility, argued that an increased inflation uncertainty raises the uncertainty about the potential return from an investment project and thus it provides incentive to delay the investment, which in turn lowers investment and output growth.[15]. Blackburn and Pelloni (2004) argued that increased inflation uncertainty exerts a negative effect on output growth, as it has adverse impact on aggregate employment in line with the Friedman (1977) hypothesis. However, in contrast to the above analyses, Dotsey and Sarte (2000) argued that an increased inflation uncertainty may increase output, based on the cash-in-advance model.[16] The essence of the argument is that return on money balances becomes more uncertain due to heightened inflation uncertainty leading to less demand for real money balances and consumption. Thus, there will be more precautionary savings by the risk averse agents. Thereby increased fund availability for investment leading to more output growth.[17].

Inflation Uncertainty and Inflation

Similarly, there are contradictory theoretical propositions in the literature about the effect of inflation uncertainty on inflation. Cukierman and Meltzer (1986) and Cukierman (1992) argue that a higher inflation uncertainty raises inflation. The argument is based on the Barro-Gordon framework, where the objective function of the policy makers along with money supply process is random. Here, the policy makers though dislike inflation, may also want to stimulate economy through

[15] Huizinga (1993) also has given similar argument. See Goel and Ram (2001) for empirical evidence of the negative impact of inflation uncertainty on investment

[16] Through human capital accumulation channel, Varvarigos (2008) also showed similar effect.

[17] A similar approach was followed by Abel (1983)

surprise inflation (Grier and Perry, 2000). Hence the public has inference problem regarding the reasons of a higher inflation, unable to judge whether higher inflation is due to more weightage to the employment by the policy makers or due to random money supply disturbance. In such a situation, a higher inflation uncertainty provides opportunity to the policy makers to adopt expansionary monetary policy and create inflation surprise and stimulate growth. This positive relation between inflation uncertainty and inflation is generally known as "Cukierman and Meltzer" hypothesis. Contrary to the above, Holland (1995) argued that a higher inflation uncertainty reduces inflation generally known as "stabilizing Fed hypothesis". This argument is based on the assumption that the central banks' objective is to achieve price stability. Hence when faced with higher inflation uncertainty, central bank would adopt tighter monetary policy to contain inflation. In case of higher inflation uncertainty a central bank reacts by reducing the money supply to avoid the welfare loss which may happen due to the uncertainty.

Output Growth Uncertainty and Output Growth

Likewise, there has been inconclusive theoretical debate about the effect of output uncertainty on output growth and inflation. In literature many theoretical explanations have been given for the effect of output uncertainty on output growth, but there is no consensus about the sign of such effect. First, proponents of business cycle models, assume that output uncertainty and output growth are not related to each other, as the determinants of the two variables are not the same. Such models assume that real factors such as technological change determines output growth, whereas, price misperceptions are responsible for the output fluctuations

(Fountas, Karanasos, and Kim, 2006).[18] Second, a number of theories suggest of a possibility of positive effect of output uncertainty on output growth. The argument of positive effect may be traced back to the idea of '*creative destruction*' proposed by Schumpeter (1942). He argued that during recession, fluctuations in output leads to more spending on research and development which in turn raises economic growth. Sandmo (1970) and Mirman (1971) also predicted a positive effect, based on the theory of saving under uncertainty. They argue that, an increased uncertainty leads to higher precautionary savings and thereby investment, in turn, have positive effect on output growth. Further, Black (1987) argue that, investments in riskier technologies will be pursued, only if the expected return from these investments is large enough to compensate for the extra risk associated with such investments. Thus a positive effect of heightened output uncertainty on output growth. Furthermore, a similar argument has put forth by Blackburn (1999) and showed that business cycle volatility raises the long-run growth, within the endogenous growth caused by learning-by-doing. Aghion and Saint-Paul (1998) and Blackburn and Galindev (2003) have also argued the possibility of a positive association between output volatility and output growth, but respectively by using ' *opportunity cost*' and ' *knowledge accumulation*' approaches. A third view in the literature, is of a negative effect of output uncertainty on output growth predicted by Pindyck (1991). Though, the negative correlation between output uncertainty and output growth, which has its root in Keynes's (1936) analysis. Keynes argues that in return estimation from an investment, entrepreneurs must take account of fluctuations in economic activity. Higher fluctuations in output leads to more risk

[18] For more detailed theoretical discussion see Friedman (1968), Phelps (1969), Lucas (1973) among others for independent association.

associated with the investment, which in turn lowers the demand for investment and hence output. Pindyck (1991) argues that such a negative effect is due to the investment irreversibility at firm level.[19] Furthermore, Ramey and Ramey (1991) show that higher uncertainty prompts firms to produce at suboptimal level, in turn lowers output growth. In a recent study, Blackburn and Pelloni (2005) within framework of stochastic monetary growth model, showed that irrespective of shocks (technology, preference, monetary) causing fluctuation in the economy, output uncertainty and output growth are negatively correlated. However, recent studies using endogenous growth model, have shown that the effect of output uncertainty on output growth will be either positive or negative depending on the nature of shocks, structural characteristics of the economy and behaviour of agents (Chowdhury, 2014b).[20] Blackburn and Pelloni (2004), using stochastic monetary growth model argue that the effect of output uncertainty on output growth depends on the shocks striking the economy. They argue that effect will be negative(positive) depending whether the nominal(real) shocks dominate.[21].

Output Growth Uncertainty and Inflation

Finally, we discuss the theoretical literature on the effect of output uncertainty on inflation. Devereux (1989) through Baro-Gordon framework and adding a stochastic element to money growth, argue that the output uncertainty raises inflation. The

[19] Irreversible investment explicate a situation, where firms can't take back the installed investment and they can delay the investment if there is opportunity to have new information about prices, costs and other market conditions. A similar argument has also been put forth by Bernanke (1983)

[20] Aghion and Howitt (2006), argued that not only irreversibility or diminishing investment, but imperfections in credit market also constrains the investment in recessions and predicts a negative relationship between output uncertainty and output growth.

[21] Also see Smith (1996), De Hek (1999) and Jones et al. (2005) for the theoretical discussion on the possibility of the effect being positive or negative

author shows that an exogenous increase in the uncertainty of real shocks leads to lower optimal amount of wage indexation of workers. A lower wage indexation makes inflation surprise more effective and thus increasing the incentive for the policy makers to create surprise inflation and this translates to a higher average inflation at the equilibrium.[22] However, through the combination of Cukierman-Meltzer hypothesis and Taylor effect, the effect may also be the negative. As Taylor effect argue a trade-off between nominal and real uncertainty and Cukierman-Meltzer hypothesis predicts a positive effect of inflation uncertainty on inflation, thus output uncertainty may have a negative effect on inflation.

However, one commonality among these theoretical literatures, is that each of these arguments predict some kind of relationship between uncertainty of inflation or output growth and average inflation or output growth. There have been abounds of literature examining the empirical relevance of these theories, but show no consensus like the contradictory theoretical propositions. Next, we briefly review some of the empirical literatures.

2.3 A Brief Review of Empirical Literature

Several studies are available in the literature examining the relationship between inflation, output growth and their uncertainty. But, like theoretical literature, there is lack of consensus about the effects of inflation and output uncertainty on inflation and output growth. One of the major concern in the literature to examine the effect of macroeconomic uncertainty on macroeconomic performance is the measurement of uncertainty. The findings are conflicting for the same group of

[22] Cukierman and Gerlach (2003), has confirmed Devereux's claim of positive effect of real uncertainty on inflation using Barro-Gordon model.

countries with same data sample, when uncertainties are measured with different methods.[23] Earlier studies[24] have used either the variance of variables or dispersion of survey of individual forecasts as a measure of inflation and output uncertainty. Most of the studies[25], find evidence in favour of Friedman's hypothesis that is, inflation uncertainty inhibits output growth. Similarly, earlier empirical literature regarding the effect of inflation uncertainty on inflation has mixed evidence, but, positively skewed in favour of Cukierman and Meltzer (1986) hypothesis namely inflation uncertainty positively effects inflation. While empirical studies regarding the effect of output uncertainty on output growth is more recent phenomenon, earlier studies[26] used cross-sectional and pooled data to examine this relationship and obtained a mixed evidence (Fountas, Karanasos, and Kim, 2006)[27].

However, after the seminal paper by Engle (1982) introducing autoregressive conditional heteroscedasticity (ARCH), and its subsequent generalisation by Bollerslev (1986) known as Generalised Autoregressive Conditional Heteroscedasticity (GARCH), most of the recent empirical studies measured uncertainty of inflation and output through ARCH/GARCH models as conditional variance of the variables. To examine the relationship between inflation, output and their uncertainty, using ARCH/GARCH techniques, as noted earlier, two approaches namely, simultaneous and two-step have been adopted. The empirical findings, however, have not reached consensus regarding the sign and direction of the impact of macroeconomic uncertainty(Inflation and output) on macroeconomic

[23]See Neanidis and Savva (2013) on this issue.

[24]See among others,Gordon (1971),Taylor (1981), Clark (1997),Judson and Orphanides (1999)

[25]See for detailed review of earlier studies in Holland (1993), Golob (1993), Davis and Kanago (2000)

[26]See among others, Kormendi and Meguire (1985), Zarnowitz and Lambros (1987), Grier and Tullock (1989), Ramey and Ramey (1995), Martin and Rogers (2000), Turnovsky and Chattopadhyay (2003), and Chatterjee and Shukayev (2006)

[27]See Kneller and Young (2001) for review on this association

performances (inflation and output growth).

Baillie, Chung, and Tieslau (1996) examining the relationship between inflation and its uncertainty, by applying ARFIMA-GARCH models for ten countries find mixed evidence.They find that the relationship depends on the level of inflation in the economies, while there is absence of any relationship in the countries with low inflation (Canada, Germany, Italy, Japan and US). But Cukierman and Meltzer hypothesis is valid in high inflation countries (Argentina, Brazil and UK). Grier and Perry (1998) find evidence for both Cukier-Meltzer hypothesis for some countries and for Holland's hypothesis for other countries among the G7 countries. Whereas, Grier and Perry (2000) using GARCH-M method do find support in favour of Cukierman-Meltzer hypothesis for the US economy. Hwang (2001) find similar results using ARFIMA-GARCH models for the US. Kontonikas (2004) incorporating asymmetry and short-run and long-run inflation uncertainty through TGARCH and component GARCH for the UK find absence of causality from inflation uncertainty to inflation. Berument and Dincer (2005) find mixed evidence for G7 countries. Higher inflation uncertainty for Canada, France, the UK and the US, lowered inflation, while, for Japan raised inflation. For the UK Ozdemir (2010) using fractionally integrated vector ARMA-BEKK MGARCH model supports Cukierman-Meltzer hypothesis. Balcilar, Ozdemir, and Cakan (2011), using parametric and non-parametric approaches for the US, Japan and the UK find evidence for a bi-directional causal relation between inflation uncertainty and inflation. Whereas, Balcilar and Ozdemir (2013) find evidence in favour of Holland's stabilisation hypothesis for Canada, France, Germany, Japan, the UK and the USA. Berument, Yalcin, and Yildirim (2009) and Berument, Yalcin, and Yildirim (2011) used stochastic volatility model to investigate the effect of inflation uncertainty on inflation for Turkish economy and find mixed evidence.

In view of the opinion that business cycle fluctuations and economic growth are independent of each other, examining the effect of output growth uncertainty, estimated through ARCH/GARCH family, on output growth is of recent origin. Caporale and McKiernan (1996) and Caporale and McKiernan (1998) examine the effect of output uncertainty on output growth by applying GARCH-M model for the UK and the US data. They find evidence in favour of Black (1987) hypothesis namely, that output uncertainty positively affects output growth. Whereas, Speight (1999) find no evidence of the relationship between output growth and its uncertainty for the UK. Dawson and Stephenson (1997) find similar evidence for 48 US states using GARCH-in-Mean. Henry and Olekalns (2002) find evidence in support of Pindyck (1991) hypothesis that is, output uncertainty negatively affects output growth. Similar evidence for 24 OECD countries has been found in Kneller and Young (2001) and by Macri and Sinha (2000) for Australia. Using EGARCH-M model, for Japanese quarterly data, Fountas, Karanasos, and Mendoza (2004) show that output uncertainty does not affect growth and there is absence of asymmetric effect of past shocks on output uncertainty. Fountas, Karanasos, and Kim (2006) for G7 countries find evidence in support of Black hypothesis except in case of Japan. In another study Fountas and Karanasos (2006) using GARCH-M model for the US, Germany and Japan find that for Germany and Japan, output growth uncertainty positively affects output growth. By applying a similar methodology for 20 OECD countries Beaumont, Norrbin, and Yigit (2008) find no evidence of any relationship between these two variables.

There are empirical studies which have examined the relationship involving inflation, output and their uncertainties, generally in a bivariate framework, either following two-step or simultaneous approaches. Grier and Perry (2000), for the US data, applying a bivariate CCC-GARCH-M model, supports second part of Friedman's (1977) argument that inflation uncertainty significantly reduces output growth. Following a two-step approach, within a bivariate framework, for Japanese data, Fountas, Karanasos, and Kim (2002) find that inflation uncertainty reduces output growth. Further, they support Holland's (1995) stablizing hypothesis that is higher inflation uncertainty lowers average inflation and failed to find any impact of output uncertainty on inflation and growth. Grier et al. (2004) and Shields et al. (2005), within GARCH-in-Mean framework, examined the relationship between inflation, output and their uncertainties for the US. Both studies find evidence that inflation uncertainty reduces output growth, while output uncertainty has positive effect. Whereas, both inflation and output uncertainty reduces inflation significantly. Elder (2004) find evidence that inflation uncertainty lowers output growth for the US economy, using threshold GARCH-M model. Bredin and Fountas (2005) employing a model similar to that of Grier et al. (2004), find mixed evidence for G7 countries, suggesting that macroeconomic uncertainty affects macroeconomic performance.

Wilson (2006), for Japanese data, by applying a bivariate EGARCH-M model find that inflation uncertainty lowers output growth over the period of 1957 to 2002, but output uncertainty does not effect inflation. For the group of G7 countries Fountas, Karanasos, and Kim (2006) find evidence that inflation uncertainty lowers economic growth and output uncertainty positively affects output growth. However, Fountas and Karanasos (2008) for the same group of countries find that inflation uncertainty does not inhibit economic growth. Bhar and Mallik (2010), using an EGARCH model and following two-step approach for the US, find that inflation uncertainty negatively affects growth, but output uncertainty does not significantly affect either output or inflation. Jha and Dang (2012) shows that inflation uncertainty affects growth in developing countries but only when inflation reaches above a certain threshold level. In addition to the above, some of the recent studies have adopted different approaches, see Neanidis and Savva (2013), Chang and He (2010) among others.

As far as India is concerned there are only few studies examining the relationship between inflation, output growth and their uncertainties. Daal, Naka, and Sanchez (2005) examine the relationship between inflation and inflation uncertainty for both developed and developing countries including India. They find mixed evidence for Cukierman-Meltzer hypothesis. Further, they find that positive inflation shocks have more effect in Latin American countries and India than negative shocks. Thornton (2006), by employing GARCH model for 1957-2005, find that inflation positively affects inflation uncertainty and inflation uncertainty has negative effect on output. Thornton (2007), using GARCH generated measure of nominal uncertainty and following the two-step approach find mixed evidence for 12 emerging markets including India. For India the evidences support the Friedman-Ball hypothesis. Similar observation was found by Rizvi and Naqvi (2009) for India, in a study for 10 Asian countries. Narayan and Narayan (2013) also found similar evidence. Further, they also find evidence in support of Black hypothesis. Chowdhury (2014a), following the two-step approach, find that there is feed-back effect between inflation uncertainty and inflation and that inflation uncertainty is detrimental to growth.

In a recent study, using GARCH and Stochastic Volatility Models, Balaji, Durai, and Ramachandran (2016) find that the relationship between inflation and inflation uncertainty is episodic, though in later periods the evidence is in support of feedback effect.

From the survey of literatures, the following points may be summarised: First, most of the studies are associated with developed countries and there is consensus about the effect of macroeconomic uncertainty on macroeconomic performance. Second, there are few studies which have examined the effect of nominal and real uncertainty on inflation and growth simultaneously. Third, for India, studies have ignored the concern raised by Brunner and Hess (1993) about asymmetric effect. Moreover, there are only few studies exclusively for India. Finally, all these studies confirm that there is ambiguity concerning the effect of nominal and real uncertainty on inflation and output growth and therefore, needs further research especially for emerging countries like India.

2.4 Data Description and Methodology

2.4.1 Description of Data

The decade of 1970 was the turning point for the Indian economy as far as price and growth is concerned. Indian economy had experience frequent episodes of high and variable inflation, for much of the 1970s and 1980s. In fact, the most volatile price behaviour was observed in 1970s, where maximum inflation recorded in the financial year 1974-75 at 25.2 percent and minimum at (-)1.1 percent in the following financial year that is in 1975-76 (Reddy, 1999). However, in subsequent decades not only the average inflation, but volatility of inflation has also declined (Chowdhury, 2014a; Reddy, 1999). Similarly, there has been a shift in growth pattern of Indian economy in 1970s. Where between 1950s and mid-1970, annual growth rate of GDP remained as low as between 3 and 4 percent per annum, the same grew by over 5 percent per annum between mid-1970 and 1990 (Mukherji, 2009). The above observations present interesting fact that, in the beginning of 1970, Indian economy not only saw a high and volatile price behaviour but also rise in growth. Since then, inflation has followed declining trend but growth kept its pace. Based on the above observations, the sample period of the study starts with April 1970. We have used monthly Index of Industrial Production (IIP) and Whole sale price Index (WPI) obtained from EPW time series database for the period of April 1971 to December 2016. Both the series has been deseasonalised after testing for the presence of seasonality using the recent methodology X-13ARIMA-SEATS of the U. S. Census Bureau (Census, 2013)[28]. Output growth (y_t) and inflation (π_t) is defined by equations 2.1 and 2.2 respectively.

$$y_t = 1200 * \ln(iip_t/iip_{t-1}) \tag{2.1}$$

$$\pi_t = 1200 * \ln(wpi_t/wpi_{t-1}) \tag{2.2}$$

The data is graphically shown in figures 2.1a-2.1b and the basic statistics are presented in table 2.1. Summary statistics of both the series output growth (y_t) and inflation (π_t), show that, both series are positively skewed and have excess kurtosis.

[28]Results are reported in Appendix in table 2.A.1.The results reveal presence of seasonality in both the series

Output growth (y_t) and inflation (π_t) both are non-normal as the null hypothesis of Jarque-Bera (1980) test for normality is rejected at 1% level of significance.

Table 2.1. Basic Statistics

Output growth			
Sample Mean	5.518	Variance	693.917
Standard Error	26.342	SE of Sample Mean	1.130
t-Statistic (Mean=0)	4.881	Signif Level (Mean=0)	0.000
Skewness	0.303	Signif Level (Sk=0)	0.004
Kurtosis (excess)	3.738	Signif Level (Ku=0)	0.000
Jarque-Bera	324.441	Signif Level (JB=0)	0.000
Inflation			
Sample Mean	6.845	Variance	81.426
Standard Error	9.024	SE of Sample Mean	0.387
t-Statistic (Mean=0)	17.677	Signif Level (Mean=0)	0.000
Skewness	0.849	Signif Level (Sk=0)	0.000
Kurtosis (excess)	3.583	Signif Level (Ku=0)	0.000
Jarque-Bera	355.805	Signif Level (JB=0)	0.000

Table 2.2. Unit Root Tests

Tests/ Variables		Growth	Inflation	Critical Values		
		T-stat	T-stat	1%	5%	10%
DFGLS	C	-22.859	-8.182	-3.445	-2.867	-2.570
	C+T	-22.854	-8.569	-3.979	-3.420	-3.132
PP	C	-38.047	-17.772	-3.442	-2.867	-2.570
	C+T	-38.047	-17.870	-3.975	-3.418	-3.131
KPSS	C	0.158	0.509	0.739	0.463	0.347
	C+T	0.125	0.036	0.216	0.146	0.119

Notes: C and $C+T$ refer two alternative specifications, with constant and with constant and a linear trend in test equations respectively.DFGLS is the augmented Dickey-Fuller test (Elliott, Rothenberg, and Stock, 1992) with generalised least squares de-trending, PP is the Phillips-Perron test (Phillips and Perron, 1988) and KPSS is the Kwiatkowski et al. (1992a) stationary test. Lag lengths for DFGLS tests are selected using Bayesian Information Criterion (BIC). For the PP and KPSS tests bandwidths are based on Newey-West automatic selection.

A battery of unit root tests have been performed to ascertain the stationarity properties of the variables output growth (y_t) and inflation (π_t), namely DFGLS due to Elliott, Rothenberg, and Stock (1992), Phillips-Perron due to Phillips and

Perron (1988) and KPSS due toKwiatkowski et al. (1992b). The results reported in table 2.2 suggest that, both variables are $I(0)$ series, that is stationary at level.

Table 2.3. Autocorrelations

Variables/Lags	4	8	12
Inflation	0.221	0.201	-0.089
Inflation SQR	0.294	0.206	0.055
Output growth	-0.025	-0.074	-0.093
Output growth SQR	0.002	0.041	0.077

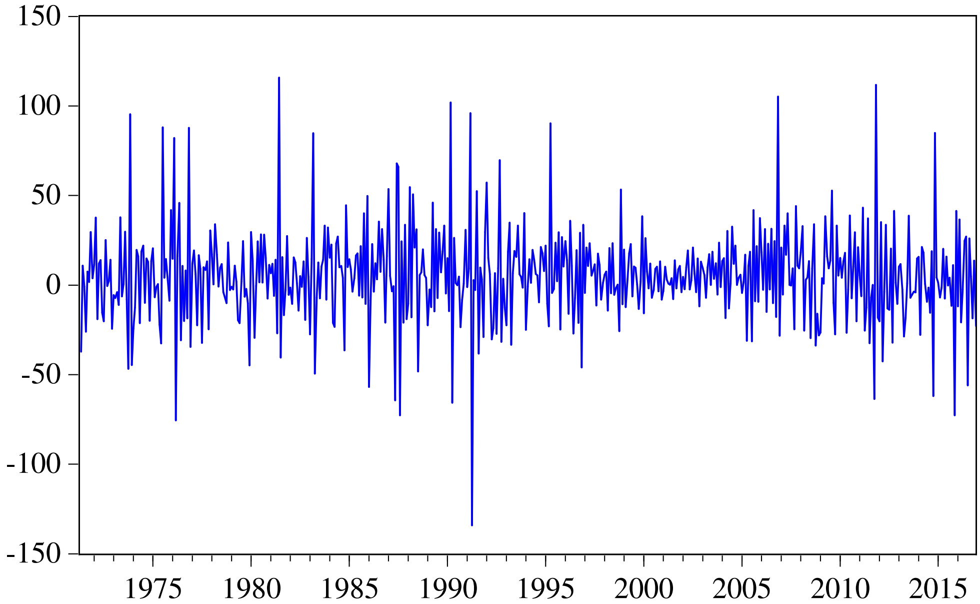
Notes: SQR refers autocorrelation for the squared lag values.

Table 2.4. Results of the L-B test for linear and squared autocorrelations

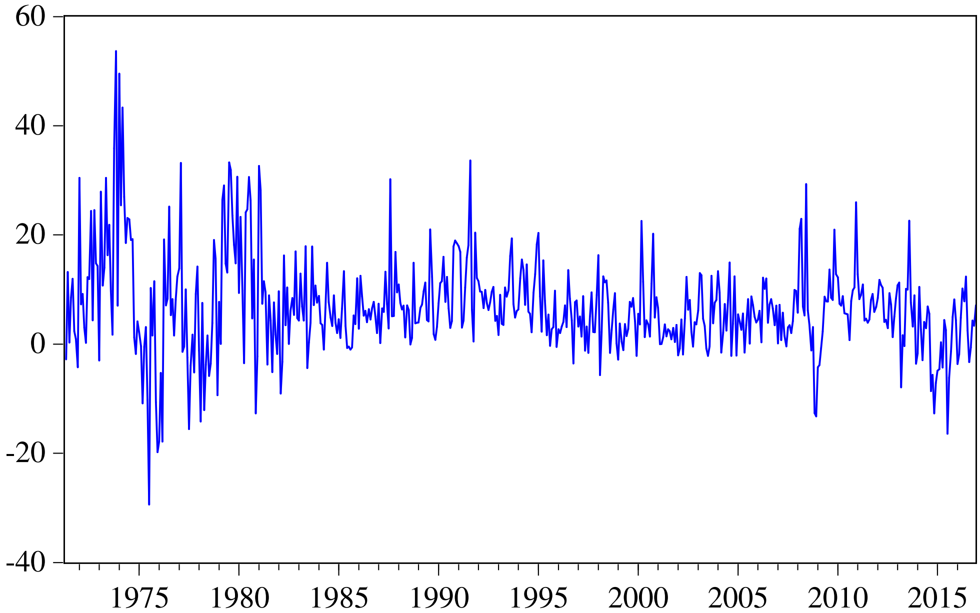
Lags	Output growth		Inflation	
	Statistic	Signif Lvl	Statistic	Signif Lvl
4	83.021	0.000	223.606	0.000
8	87.404	0.000	342.490	0.000
12	103.223	0.000	372.086	0.000
L-B test for the squared autocorrelations				
4	27.563	0.000	230.092	0.000
8	28.888	0.000	350.405	0.000
12	34.058	0.001	384.324	0.000

The autocorrelations, results presented in table 2.3 and Ljung and Box (1979)'s LB test, statistics presented in table 2.4 for serial correlation suggest that variables are serially dependent[29]. The Ljung and Box (1979) test statistics for the square of the variables also show that there is presence of conditional heteroscedasticity in the variables.

[29]Cumulated Periodogram test based on frequency domain techniques also performed to confirm the serial dependency (results reported in appendix in Table 2.A.2) and results corroborate the LB test findings.



(a) Output Growth



(b) Inflation

Figure 2.1. Time-series plots of Data

2.4.2 Econometric Methodology

In this section, we discuss the model used for testing the effects of output growth and inflation uncertainty on the levels of output growth and inflation. The theoretical discussions show that there may exist a spillover effect between volatility of inflation(output) and output (inflation). Further, it is now well accepted that positive and negative shocks to inflation(output) of equal magnitude have asymmetric effect on level of output growth and inflation. Therefore, in contrast to the existing literature, we chose Vector Autoregressive Moving Average (VARMA) GARCH-in-Mean Model, which allows us to incorporate asymmetric as well spillover effects. Moreover, this model may be estimated using simultaneous approach, which considered to be more efficient than two-step approach. We discuss Vector Autoregressive Moving Average (VARMA) GARCH-in-Mean Model[30]. Next, following Grier et al. (2004), we introduce asymmetry in the model. We also describe the method of estimation briefly. At the end, we specify some tests for the appropriateness of the model for the given data sample.

2.4.3 VARMA-GARCH-in-Mean Model

A Vector Autoregressive Moving Average (VARMA) GARCH-in-Mean Model for the variables output growth (y_t) and inflation (π_t), may be represented as in equation 2.3 and 2.4 where, following Grier et al. (2004), the conditional standard deviation of output growth (y_t) and inflation (π_t) are included as explanatory variables in each

[30] We used bivariate GARCH model, as pointed by Chua, Kim, and Suardi (2011), that bivariate models produces superior uncertainty proxy than univariate GARCH models.

mean equations.

$$Y_t = \mu + \sum_{i=1}^{p} \Lambda_i Y_{t-i} + \Psi\sqrt{h_t} + \sum_{j=1}^{q} \Theta_j \epsilon_{t-j} + \epsilon_t$$

$$\epsilon_t | I_t \sim (0, H_t) \tag{2.3}$$

$$H_t = \begin{bmatrix} h_{yy,t} & h_{y\pi,t} \\ h_{y\pi,t} & h_{\pi\pi,t} \end{bmatrix}$$

$$H_t = C_0 C_0' + A_{11}\epsilon_{t-1}\epsilon_{t-1}' A_{11} + B_{11} H_{t-1} B_{11}' \tag{2.4}$$

the values of p and q may be chosen by using any information criteria and I_t represents the information set at time t.

Here,

$$Y_t = \begin{bmatrix} y_t \\ \pi_t \end{bmatrix}; \sqrt{h_t} = \begin{bmatrix} \sqrt{h_{y,t}} \\ \sqrt{h_{\pi,t}} \end{bmatrix}; \epsilon_t = \begin{bmatrix} \epsilon_{y,t} \\ \epsilon_{\pi,t} \end{bmatrix}$$

$$\mu = \begin{bmatrix} \mu_y \\ \mu_\pi \end{bmatrix}; \Lambda_i = \begin{bmatrix} \lambda_{yy}^i & \lambda_{y\pi}^i \\ \lambda_{\pi y}^i & \lambda_{\pi\pi}^i \end{bmatrix}$$

$$\Psi = \begin{bmatrix} \psi_{yy} & \psi_{y\pi} \\ \psi_{\pi y} & \psi_{\pi\pi} \end{bmatrix}; \Theta_j = \begin{bmatrix} \theta_{yy}^i & \theta_{y\pi}^i \\ \theta_{\pi y}^i & \theta_{\pi\pi}^i \end{bmatrix}$$

In equation 2.3, the coefficients λ_{yy}^i and $\lambda_{\pi\pi}^i$ for $i = 1, 2, ..., p$ are the effects of own lags in the conditional mean equation for output growth (y_t) and inflation(π) respectively. Similarly, the coefficients $\lambda_{y\pi}^i$ and $\lambda_{\pi y}^i$ are the effects of inflation and output growth respectively on output growth and inflation. The main parameters of interest to detect the effect of output growth and inflation uncertainty on output growth and inflation are ψ_{yy}, $\psi_{y\pi}$, $\psi_{\pi y}$ and $\psi_{\pi\pi}$. The coefficients ψ_{yy} and $\psi_{y\pi}$ respectively show the effect of output and inflation uncertainty on output growth. The coefficients $\psi_{\pi\pi}$ and $\psi_{\pi y}$ denote the effect of inflation and output growth uncertainty respectively on inflation.

H_t, the variance-covariance matrix, to be positive definite for all values of ϵ_t in the sample is necessary, to estimate the above model, with maximum likelihood. In the BEKK model proposed by Engle and Kroner (1995), by construction, the variance-covariance matrix is positive definite. However, it is to be noted that BEKK model presented in equation 2.4 is symmetric in nature and does not incorporate the asymmetric effect of positive and negative shocks in the volatility of the output growth and inflation. To accommodate the asymmetric effect[31] of output growth and inflation uncertainty, we follow Grier et al. (2004), and the equation 2.4 is re-written as

$$H_t = C_0C_0' + A_{11}\epsilon_{t-1}\epsilon_{t-1}'A_{11} + B_{11}H_{t-1}B_{11}' + D_{11}\epsilon_{t-1}\epsilon_{t-1}' \tag{2.5}$$

Where,

$$C_0 = \begin{bmatrix} c_{yy} & c_{y,\pi} \\ 0 & c_{\pi\pi} \end{bmatrix}; A_{11} = \begin{bmatrix} \alpha_{yy} & \alpha_{y\pi} \\ \alpha_{\pi y} & \alpha_{\pi\pi} \end{bmatrix}; B_{11} = \begin{bmatrix} \beta_{yy} & \beta_{y\pi} \\ \beta_{\pi y} & \beta_{\pi\pi} \end{bmatrix}$$

$$D_{11} = \begin{bmatrix} \delta_{yy} & \delta_{y\pi} \\ \delta_{\pi y} & \delta_{\pi\pi} \end{bmatrix} and\ \epsilon_t = \begin{bmatrix} \epsilon_{y,t} \\ \epsilon_{\pi,t} \end{bmatrix}$$

The above asymmetry captures the concept of "good" and "bad" news. The good or bad news is decided based on the values of residuals. In this particular model, a

[31] Chua, Kim, and Suardi (2011) also have suggested that asymmetric properties must be accomodated in the model specification to avoid misspecification.

negative residuals represent 'bad news' which occurs whent output growth is lower than expected. In contrast inflation more than expected is considered as bad news and represented by positive residual. Symbolically, we may define $\epsilon_{y,t}$ as $min\,[\epsilon_{y,t}, 0]$ as bad news about output growth or to say negative innovation. Similarly, $\epsilon_{\pi,t}$ as $max\,[\epsilon_{\pi,t}, 0]$ may be defined as bad news about inflation that is to say a positive innovation of inflation. The above model specified in equations 2.3 and 2.5 may be called Asymmetric VARMA-GARCH-in-Mean Model. The symmetric BEKK model is a special case of the above formulation for $\delta_{i,j} = 0$ for all i and j.

2.4.4 Estimation and Specification

Under the assumption of normality of $\epsilon_t|I_t$, with a given sample observations of T, the log-likelihood function may be represented as follows;

$$L(\theta) = -\frac{1}{2}\sum_{t=1}^{T}(ln|H_t|) + \epsilon_t' H^- 1_t \epsilon_t \tag{2.6}$$

Where, θ is the vector of all parameters in the model. Obtaining the Maximum Likelihood estimates of the parameters require optimisation of a highly non-linear objective function which is conditional to some starting values of H_t and other relevant parameters. For this we have used standard gradient search algorithm known as BFGS. However, imposing diagonal and asymmetry restriction, without testing may create potentially serious specification error (Grier et al., 2004).Therefore, in the covariance model, we allow for the innovations of output growth and inflation to have diagonal as well asymmetric effects on the conditional variance and covariance of each series. In addition to the above, we test the following hypotheses to examine the the statistical appropriateness of other parameters.

i) Test for the diagonal VARMA

$$H_0 : \lambda^i_{y\pi} = \lambda^i_{\pi y} = \theta^j_{y\pi} = \theta^j_{\pi y} = 0$$

ii)Test for GARCH

$$H_0 : \alpha_{ij} = \beta ij = \delta_{ij} = 0, \quad \text{for} \quad i, j = \pi, y$$

iii) Test for GARCH-in-Mean effect

$$H_0 : \psi_{ij} \quad \text{for} \quad i, j = \pi, y$$

iv) Test for asymmetry

$$H_0 : \delta_{ij} = 0 \quad \text{for} \quad i, j = \pi, y$$

v) Test for Diagonal GARCH

$$H_0 : \alpha_{y\pi} = \alpha_{\pi y} = \beta_{y\pi} = \beta_{\pi y} = \delta_{y\pi} = \delta_{\pi y} = 0$$

2.5 Empirical Results

Prior to estimating the VARMA-GARCH-in-Mean model specified in equations 2.3 and 2.5, we test for the presence of ARCH effects using LM test. Results in table 2.5, confirm presence of ARCH effects both at lag 4 and lag 8 in both the series. In addition to this, as the preliminary tests reveal variables do not follow a normal distribution. Assumption of normally distributed standardised innovations, would be contestable. Therefore, following the suggestion of Weiss (1986) and Bollerslev and Wooldridge (1992) and employed by Grier et al. (2004), we used quasi-maximum likelihood estimates based on the assumption of robust standardised residuals to have asymptotically valid inference.

2.5.1 Specification Tests

Before analysing the estimates of the joint estimation of the main model represented in equations 2.3 and 2.5 in table 2.6. In this section, we discuss the tests on the appropriateness of the specifications adopted to examine the relationship among the study variables. The hypotheses and test results are in tables 2.7– 2.10. First, the results for the test of conditional homoscedasticity in these data, reported in table 2.7 exhibit presence of significant conditional heteroscedasticity. To be homosecdastic, the coefficients of matrices A_{11}, B_{11} and D_{11} that is coefficients α_{ij}, β_{ij} and δ_{ij} for all i, $j = y, \pi$, jointly should be insignificant. But, the null is rejected at 1% level of significance, they are actually individually also significant, suggesting the presence of conditional heteroscedasticity.

Second, the hypothesis of a diagonal covariance process requires that the non-diagonal coefficients that is α_{ij}, β_{ij} and δ_{ij} for all i,$j = y, \pi$ and $i \neq j$ should be jointly insignificant. In contrast, the results show that they are significant at 1% level of significance, thus rejects the null hypothesis. Here, the insignificance of the coefficients α_{ij} for all i,$j = y, \pi$ and $i \neq j$, shows that allowing non-diagonality does not increase the persistence of the conditional variances. However, the above significant coefficients, show that lagged squared innovations in each series do have effect on the conditional variance of other series (Grier et al., 2004).

The third hypothesis that of a symmetric covariance process, which may be tested by jointly testing the significance of the coefficients of the matrix D_{11} that is coefficients δ_{ij} for all i, $j = y, \pi$. The test results show that jointly coefficients are significant at 1% level of significance as well individually coefficients are significant at conventional level of significance. Moreover, *ceteris paribus*, the response of the output growth to the own variance is asymmetric, that is negative growth shocks raise uncertainty more than positive shocks, is revealed by the fact that both α_{11} and δ_{11} are significant.

In similar manner, the significant α_{22} and δ_{22} coefficients show that, *ceteris paribus*, response of inflation to it's variance is asymmetric that is a negative inflation leads to less inflation volatility than of a positive innovation of same magnitude.

Table 2.5. LM test for ARCH effect

Lags	Inflation		Output Growth	
	Statistic	Significance Level	Statistic	Significance Level
4	30.616	0.000	119.225	0.000
8	30.884	0.000	125.118	0.000

In summary, the results of the above tests, reveal that inflation and output growth is conditionally heteroscedastic, innovations to output growth and inflation significantly affect the conditional variance of inflation and output growth. It also highlights the importance of sign and size of the innovations of both output growth and inflation. These results also show that the methodological approach, allowing for spillover, asymmetry and non-diagonal covariance process, adopted to investigate the relationships among output growth, inflation and their uncertainty is appropriate. Moreover, we also evaluated the model with diagnostic tests.

First, we test the standardised residuals $\nu_{jt} = \epsilon_{j,t}/\sqrt{h_{jt}}$ for $j = y, \pi$ and their corresponding squares, to examine the fourth-order linear dependence by using LB test. The results in table 2.8 show that there is no fourth-order linear dependence. Similar conclusions may be arrived for the eighth and twelfth-order linear dependence. We also employ multivariate-Q and ARCH tests, for the jointly standardised residuals. The results in table 2.9, justify the null hypothesis of no

Table 2.6. Asymmetric Multivariate GARCH-in-Mean Model

Variable	Coeff	Std Error	T-Stat	Signif
Conditional Mean Equation: Output Growth(y_t)				
μ_y	26.105	3.640	7.171	0.000
λ_{yy}^1	-0.754	0.100	-7.543	0.000
λ_{yy}^2	-0.287	0.047	-6.145	0.000
$\lambda_{y\pi}^1$	0.751	0.154	4.867	0.000
$\lambda_{y\pi}^2$	-0.158	0.086	-1.843	0.065
θ_{yy}^1	0.297	0.098	3.041	0.002
$\theta_{y\pi}^1$	-0.434	0.171	-2.530	0.011
ψ_{yy}	**-0.468**	**0.129**	**-3.620**	**0.000**
$\psi_{y\pi}$	**-1.156**	**0.289**	**-4.000**	**0.000**
Conditional Mean Equation: Inflation(π)				
μ_π	-1.100	0.282	-3.893	0.000
$\lambda_{\pi y}^1$	0.072	0.012	6.022	0.000
$\lambda_{\pi y}^2$	0.030	0.012	2.521	0.012
$\lambda_{\pi\pi}^1$	1.043	0.017	59.605	0.000
$\lambda_{\pi\pi}^2$	-0.158	0.009	-16.948	0.000
$\theta_{\pi\pi}^1$	-0.065	0.013	-5.036	0.000
$\theta_{\pi y}^1$	-0.752	0.031	-24.196	0.000
$\psi_{\pi\pi}$	**0.045**	**0.012**	**3.740**	**0.000**
$\psi_{\pi y}$	**0.034**	**0.015**	**2.272**	**0.023**
Conditional Variance Equation				
C_{yy}	18.620	1.729	10.767	0.000
$C_{y\pi}$	-0.142	0.481	-0.294	0.768
$C_{\pi\pi}$	0.002	0.246	0.007	0.994
α_{yy}	-0.397	0.061	-6.556	0.000
$\alpha_{y\pi}$	0.023	0.021	1.069	0.285
$\alpha_{\pi y}$	0.435	0.149	2.911	0.004
$\alpha_{\pi\pi}$	0.240	0.099	2.413	0.016
β_{yy}	0.192	0.211	0.914	0.361
$\beta_{y\pi}$	0.064	0.020	3.233	0.001
$\beta_{\pi y}$	-0.097	0.181	-0.539	0.590
$\beta_{\pi\pi}$	0.938	0.023	41.234	0.000
δ_{yy}	0.712	0.143	4.970	0.000
$\delta_{y\pi}$	-0.034	0.026	-1.314	0.189
$\delta_{\pi y}$	0.255	0.191	1.332	0.183
$\delta_{\pi\pi}$	-0.202	0.143	-1.418	0.156

Notes: The details of the parameters are in section 2.4.3

Table 2.7. GARCH Specification Tests

Hypothesis	Coefficient Restrictions	P-value
Diagonal VARMA	$H_0 : \alpha^i_{12} = \alpha^i_{21} = \theta^i_{12} = \theta^i_{21} = 0$	0.000
No GARCH	$H_0 : a_{ij} = b_{ij} = d_{ij} = 0$ for all i, j	0.000
No GARCH-in-Mean	$H_0 : \psi_{ij} = 0$ for all i, j	0.000
No Asymmetry	$H_0 : d_{ij} = 0$ for all $i, j = 1, 2$	0.000
Diagonal GARCH	$H_0 : a_{12} = a_{21} = b_{12} = b_{21} = d_{12} = d_{21} = 0$	0.000

Notes: P-value refers probability values for the rejection of hypotheses

Table 2.8. Residual Diagnostics

	Output growth Residuals ($\epsilon_{y,t}$)				Inflation Residuals($\epsilon_{\pi,t}$)			
	LB test		LB sqr test		LB test		LB sqr test	
Lags	Statistic	Signif Lvl	Statistic	Signif Lvl	Statistic	Signif Lvl	Statistic	Signif Lvl
4	4.739	0.315	0.090	0.999	3.438	0.487	0.926	0.921
8	7.750	0.458	1.614	0.991	10.259	0.247	3.143	0.925
12	18.533	0.100	6.190	0.906	38.122	0.000	7.185	0.845

Notes: LB test and LB sqr respectively refers test LB test for the residuals and squared residuals

Table 2.9. Multivariate Q-statistic and ARCH test on jointly standardized residuals

lags	Multivariate Q		Multivariate ARCH	
	χ^2	significance level	statistics	significance level
4	10.955	0.812	39.290	0.325
8	26.062	0.761	65.240	0.701
12	66.699	0.038	94.550	0.819

Table 2.10. Moment Based Test

Variables	Test	Significance level
Output	0.023	0.879
Inflation	0.099	0.753
Covariance	0.051	0.821

Notes: These tests are performed on the standardised residuals of a series based on moment conditions.

linear dependence at fourth, eighth and twelfth order and ARCH effect at fourth, eighth and twelfth lags.

In addition to these, we also examine standardised residuals of a series based on moment conditions. The results are in table 2.10. The null hypothesis of $E(\nu_{jt}) = 0$ and $E(\nu_{jt}^2) = 1$ for a well specified-model (Grier et al., 2004), cannot be rejected. Similarly, $E(\epsilon_{i,t}^2) = h_{i,t}$ for $i = y, \pi$ and $E(\epsilon_{y,t}), \epsilon_{\pi,t} = h_{y\pi,t}$ predicted from the model cannot be rejected.

Overall, the above analyses show that the model is well-specified and relevant for the present sample to examine the concerned relationship.

2.5.2 Results for VARMA GARCH-in-Mean Model

The results discussed in the previous section, show that conditional mean and variance-covariance processes defining the output growth and inflation are well described by the model in equations 2.3 and 2.5. In this section, we discuss the results of the model specified in these equations to examine the effects of uncertainty on output growth and inflation and find out empirical relevance of the hypotheses discussed in section 2.2. As discussed in the methodology, our econometric approach is flexible enough to capture both spillover and asymmetry in responses of output growth and inflation due to their uncertainties.

First, we consider the effect of inflation uncertainty on output growth and inflation. The Friedman (1977) and Pindyck (1991), hypotheses that inflation uncertainty lowers output growth implies a negative and significant coefficient $\psi_{y\pi}$ of coefficient matrix Ψ. While Dotsey and Sarte's (2000) hypothesis that inflation uncertainty helps to raise output growth implies a positive and significant value of the coefficient $\psi_{y\pi}$ of the mean equation presented in equation 2.3. The results in table 2.6 report the estimated coefficients. The estimated coefficient $\psi_{y\pi}$ is negative (-1.156) and significant at 1% or better (t-statistics -4.00). Thus our result provides strong empirical evidence for the Friedman (1977) hypothesis. It shows that inflation uncertainty has a significant and negative effect on output growth.

Similarly, about the effect of inflation uncertainty on inflation, the hypotheses of Cukierman and Meltzer (1986) and Cukierman (1992) requires a significant and positive value of the coefficient $\psi_{\pi\pi}$ of the coefficient matrix Ψ of equation 2.3. While the hypothesis of Holland (1995) requires a negative and significant value of the coefficient $\psi_{\pi\pi}$. The estimated value of the coefficient from the table 2.6 is positive (0.045) and significant at 1% level or better. Thus the empirical results show that Cukierman and Meltzer (1986) and Cukierman (1992) is valid, that is an increasing inflation uncertainty creates more inflation.

The effect of output uncertainty on growth and inflation may be assessed by evaluating the value and sign of the coefficients ψ_{yy} and $\psi_{\pi y}$ respectively. The hypotheses that output uncertainty enhance output growth proposed by Black (1987) and output uncertainty inhibits growth proposed by Pindyck (1991) requires that coefficient ψ_{yy} should be positive and significant and negative and significant respectively. The estimated coefficient in table 2.6 reveal that in the present case, Pindyck's (1991) hypothesis is valid. That is, the view that risky output growth is positively correlated with more output growth, does not hold true, rather, output uncertainty lowers output growth in India. In similar line, there are two opposite hypotheses about the effect of output uncertainty on inflation contradictory to each other. While Fuhrer (1997) says that output uncertainty has a negative effect on inflation, in opposite, Devereux (1989) says that output uncertainty has a positive effect on inflation. A positive (0.034) and significant estimated value of the coefficient $\psi_{\pi y}$, lends support to the Devereux's (1989) argument, that is output uncertainty positively effects inflation. In addition, the results also reveal that inflation uncertainty has more impact on the growth and inflation than output uncertainty.

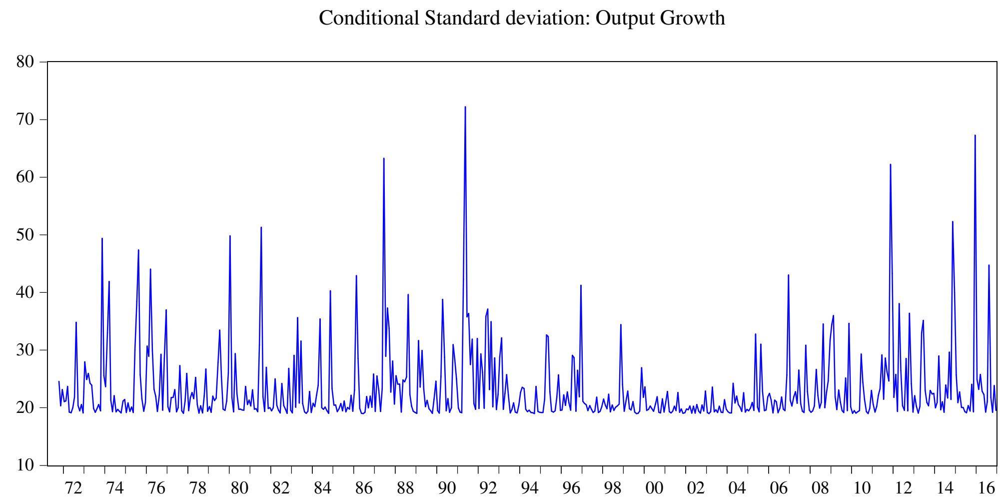


Figure 2.2. Plot of Conditional Standard Deviation of Output Growth

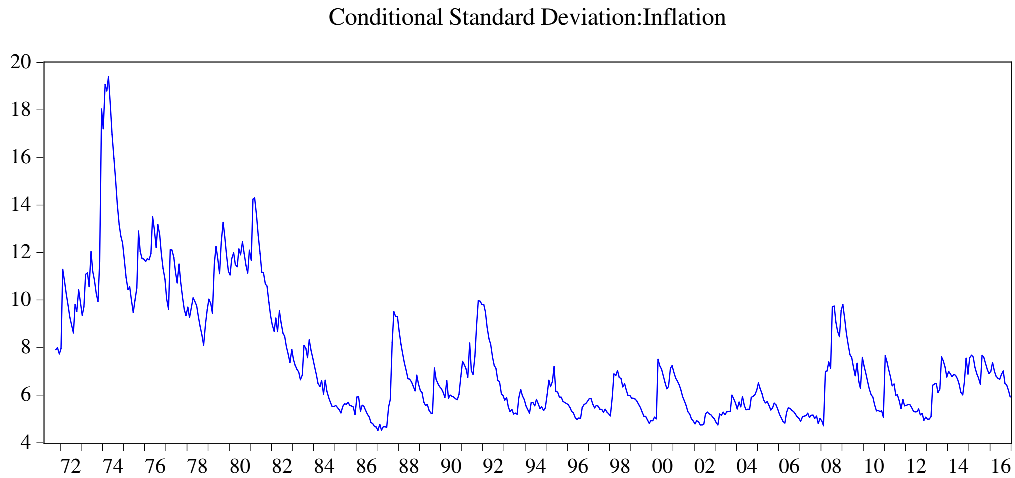


Figure 2.3. Plot of Conditional Standard Deviation of Inflation

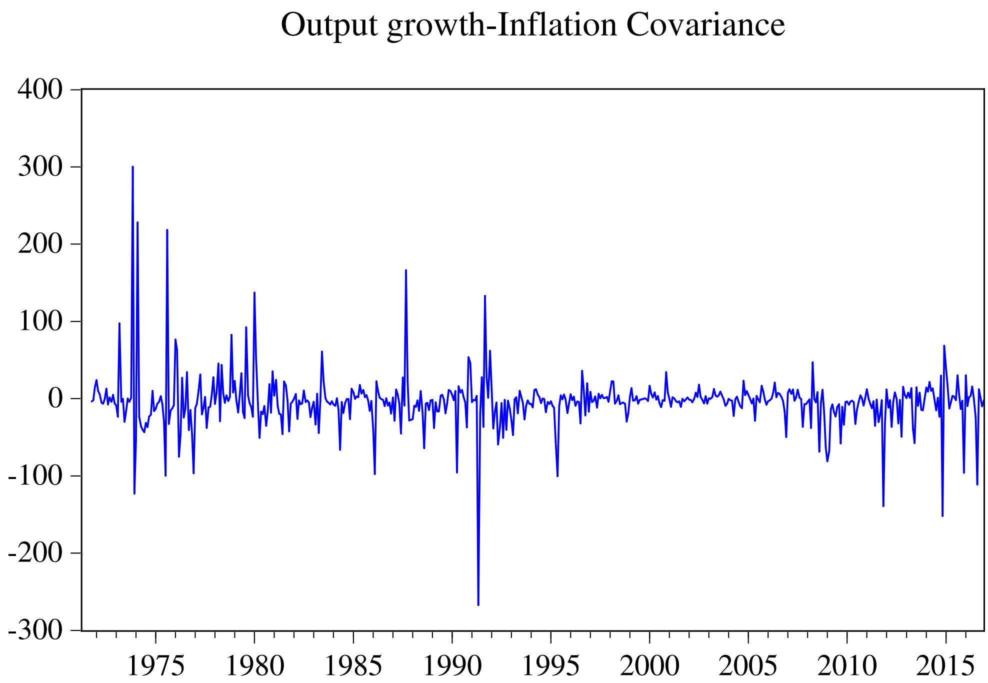


Figure 2.4. Plot of Covariance of Output Growth and Inflation

2.6 Discussion

The effect of inflation uncertainty on output growth is detrimental as the coefficient $\psi_{y\pi}$ is negative and significant. The evidence support the Friedman (1977) and Pindyck (1991) hypothesis and is in line with the results of Thornton (2006) and Chowdhury (2014a). The effect of inflation uncertainty on inflation is positive (a positive and significant $\psi_{\pi\pi}$) and validates the Cukierman-Meltzer hypothesis, indicating that Indian Central Bank (Reserve Bank of India) follows an opportunistic approach and raise inflation. The results are in line with Asghar et al. (2011), Chowdhury (2014a), Balaji, Durai, and Ramachandran (2016) and contrary to the Thornton (2007), Daal, Naka, and Sanchez (2005). The difference in results could be attributed to the difference in methodologies. They have ignored the spillover and asymmetric effects. Moreover, they followed a two-step approach instead of simultaneous approach, which cast doubt on the results due to the issues raised by Pagan (1984). Further, the results also reveal that RBI prefers output stabilisation rather than price stability (Fountas, Karanasos, and Kim, 2006). Moreover,the results are in concurrence with the low value (3 on scale of 0 to 15, 0 being lowest, Dincera and Eichengreenb (2014)) of the central bank Transparency Index associated with Reserve Bank of India. As more independent central bank would have more stronger anti-inflation preference than the government and would respond a high inflation uncertainty by reducing inflation (Rogoff, 1985; Alesina and Summers, 1993; Fountas, Karanasos, and Kim, 2006), there would be more incentive to reduce inflation in response to higher inflation uncertainty as it will keep the inflation uncertainty at lower level, and hence central bank can attain lower inflation as well as higher output growth as inflation uncertainty hurts output growth.

Moreover, the negative and significant value of ψ_{yy}, reveal that output uncertainty harms growth. A positive and significant value of $\psi_{\pi y}$, shows that output uncertainty raises inflation and is a reflection of RBI's opportunistic policy framework (Devereux, 1989). These two results show that fluctuation in economic growth not only harms growth prospects, but also raise inflation and have two cascading effect on overall welfare. Overall, our results show that macroeconomic uncertainty affects macroeconomic performance and have welfare cost.

2.7 Conclusion and Policy Recommendations

There have been spurt in the theoretical and empirical research regarding the role of macroeconomic uncertainty in macroeconomic performance, after the Friedman, 1977 informal theoretical argument and this further attracted the policy makers attention after the global financial crises in 2007-08 (Bloom, 2009, See). However, most of the studies are associated with developed countries, there is still scant literature for emerging countries like India. This study, contributes to this line of literature, by examining the effect of nominal(inflation) and real(output) uncertainty on inflation and output growth for India. We employed a simultaneous approach with in the framework of GARCH model, for the period April, 1971 to December, 2016. Our model also incorporates the spillover and asymmetric effect to account the issue raised by Brunner and Hess (1993).

The basic statistics, results of ARCH LM test show the presence of ARCH effect and non-normal distribution in both inflation an output growth variables. Further, results of the specification tests show the presence of asymmetric effect of positive and negative shocks. Moreover, besides specification tests, the diagnostic tests reveal appropriateness of the model employed to investigate the relationship among inflation, output growth and nominal(inflation) and real(output) uncertainty.

Our result are in favour of Cukierman-Meltzer hypothesis. That is, inflation uncertainty positively affects inflation and provides support to the notion of opportunistic policy framework of Indian central bank. Further, results show that inflation uncertainty is detrimental to economic growth supporting the Friedman (1977) and Pindyck's (1991) hypotheses. Whereas, real(output) uncertainty has negative(positive) and significant effect on output growth(inflation). This validates the arguments putforth by Pindyck (1991) and Devereux (1989) about the effect of output uncertainty on growth and inflation. Results also reveal that negative and positive shocks of equal magnitude do not have equal effect.

Our results raises the need of a number of policy actions. First of all, it shows the importance of low, stable and predictable inflation. The evidence for the adverse impact of both nominal and real uncertainty on growth, warrants the need of long-term and more effective counter-cyclical macro-management. Further, there is need to quick policy responses to the inflation shocks, thereby reducing inflation uncertainty and hence less welfare cost via reduction in growth.There is also need to create credibility regarding the policy responses of policy makers and institutions among the people as the success of the stabilising policies depends on the degree of institutional quality of the country . This can be achieved by adopting information dissemination and a transparent approach in policy making.

Appendix

2.A Tables

Table 2.A.1. Seasonality Tests

Variables	Tests	Statistics	DF	P-Value
IIP	BM	178.123*	11	-
	NT	375.905	11	0.000
	MV	5.970*	44	-
WPI	BM	54.596*	11	-
	NT	385.301	11	0.000
	MV	17.555*	44	-

Notes:BM refers between months test for the presence of seasonality assuming stability.NT refers non-parametric (Kruskal-Wallis) test of seasonality assuming stability. MV refers moving seasonality test. * indicates significance at 1 % or better.

Table 2.A.2. Cumulated Periodogram Test

Variables	Inflation	Output growth	Signif Lvl	Limits
Maximum Gap	0.6064	0.2178	1%	0.0832
At Frequency	0.2291	1.7017	5%	0.0694
			10%	0.0623

* * * * *

3 | Uncertainty and effectiveness of Monetary policy: A Bayesian Markov Switching-VAR analysis

3.1 Introduction

Over the years, theoretical and empirical literature employing different methodology led to a general consensus that monetary policy affects macroeconomy at least in the short-run (Romer and Romer, 1989; Bernanke and Blinder, 1992; Christiano, Eichenbaum, and Evans, 1994a; Christiano, Eichenbaum, and Evans, 1994b). In the literature, alternative channels through which monetary policy transmission takes place have been explained. These include interest rate channel (Hicks, 1937; Taylor, 1995), credit channel (Bernanke, 1986; Bernanke and Blinder, 1992; Ben and Gertler, 1995), asset prices channel (Meltzer, 1995), exchange rate channel (Obstfeld and Rogoff, 1995), expectation channel (Taylor, 1995; Blinder, 1998) and balance sheet channel (Mishkin, 1996)[1]. These recognised channels are not mutually exclusive, and that more than one channel can work simultaneously and achieve the policy objective(s). However, the empirical studies over the years have not yet reached to any agreement regarding the working and effectiveness of these channels (Ben and Gertler, 1995). Often the term "black box" is used to describe the monetary policy

[1]See Meltzer (1995), Mishkin (1996), and Mishkin (2001),Paramanik and Kamaiah (2014) and Cevik and Teksoz (2013) for theoretical discussions on these channels

mechanism by the economists.

The effectiveness of the transmission channels depend on the economic structure, development of financial and capital markets, economic conditions among other factors of an economy (Cevik and Teksoz, 2013). As these factors vary across developed and developing countries, there is no reason to believe that monetary policy mechanism would be same for developed and developing countries (Mishra, Montiel, and Sengupta, 2016). These observations led to huge empirical literature to analyse the monetary policy operations for both developed and developing countries contingent to specific aspect of different economies. However, the global financial crisis (GFC) of 2007-08, which led to severe decline in real activity and dismal economic recovery in a number of countries (Castelnuovo, Lim, and Pellegrino, 2017), has sparked the debate about the effect of uncertainty on macroeconomy. In addition, the slow recovery following the policy actions and the seminal work by Bloom (2009), led to a rejuvenating interest among researchers and policy makers to examine the role of uncertainty in monetary policy transmission.[2] The theoretical discussion on the role of uncertainty on general policy effectiveness can be traced back to Brainard (1967). The author argue that the impact of policy actions will not be of same scale when the assumption of certainty is relaxed and the diversion becomes more in presence of multiple objectives and policy tools. Furthermore, Sengupta (2014) asserted that effects of monetary policy on real variables keep changing with time and this can be attributed to different kinds of uncertainties. Whilst, the empirical literature examining the dependence of monetary transmission on the structure, development and other aspects of the economy is growing, the role

[2]The increasing importance of 'portfolio balance channel' and 'expectations' channel during global financial crisis (Yellen, 2011; Joyce, Tong, and Woods, 2011), also emphasise the need to study the effect of uncertainty on monetary policy transmission

of uncertainty in influencing the monetary policy effectiveness has been ignored. However, after the GFC and Bloom's (2009) seminal work, there is a spurt in the empirical literature examining the role of uncertainty in influencing the monetary policy transmission.

The concept of uncertainty associated with Knight (1921) is inability of people to forecast the likelihood of events happening in future. A closely related concept is risk which refers to a known probability distribution over a set of events (Castelnuovo, Lim, and Pellegrino, 2017). Though, theoretically these two concepts are different but hard to differentiate empirically or in the data analysis(Castelnuovo, Lim, and Pellegrino, 2017). To the extent of literature, the term uncertainty includes both uncertainty (Knight's definition) and risk. Moreover, there is no perfect measure of uncertainty and a range of proxies like volatility of stock market or GDP has been used (Bloom, 2014). One reason to use the volatility is unavailability of perfect measure of uncertainty. Another fact is that more the series is volatile more difficult to forecast, an integral component of Knight's (1921) definition of uncertainty.

There is a general consensus that a heightened uncertainty dampens monetary policy effectiveness. This is in line with the theoretical propositions by Bernanke (1983), Dixit and Pindyck (1994) and more recently by Bloom (2009) and Aastveit, Natvik, and Sola (2013) among others. The theoretical propositions have explained various mechanism through which uncertainty influences the effectiveness of monetary policy.[3]. One of the widely discussed and accepted explanation for role of uncertainty to dampen the effectiveness of monetary policy is based on the 'real option theory'. The theory suggests that, in presence of some form of fixed costs and partial irreversibility associated with the investment and hiring process,

[3]See (Bloom, 2009) and references therein for detailed theoretical mechanism

a heightened uncertainty motivates agents to adopt 'wait and see' approach and postpone their decisions, thus weakening the impact of monetary policy (Bloom, 2009; Bloom, Bond, and Van Reenen, 2007). Another, explanation is based on the fact that an increased uncertainty may lead to increase risk premia and thus cost of financing, which reduces micro and macro growth (Bloom, 2014). Further, during uncertain times, a higher precautionary savings by risk averse agents could also lower the effectiveness of monetary policy on real economy (Bloom, 2014).

In this backdrop, the main goal of the present study is to empirically examine the impact of monetary policy contingent to the prevailing uncertainty in the Indian economy. In other words, we examine how different the effect of monetary policy will be in low and high uncertainty regimes in India. To conduct the empirical exercise, we chose the class of Markov-switching model, which allows us to divide the sample into high and low uncertainty regimes endogenously. Moreover, it efficiently captures the dynamics of the process in a co-integration space. To this end, we make use of two-state Bayesian Markov Switching Vector Auto-regression (BMSVAR) to the monthly data over the period of April 1991 to December 2016. Our model includes a standard set of macroeconomic indicators,like output growth (Index of industrial production), inflation(Whole sale price index) and weighted call money rate (indicator for monetary policy). The two-state MSVAR allows us to separate the economy into low and high uncertainty regimes. The regime-dependent impulse response functions due to Ehrmann, Ellison, and Valla (2003), enable us to examine the differential effect of the monetary policy during high and low uncertainty regimes.

The present study fills the void in the literature as previous studies are restricted to developed countries only. Further, the findings of the study are relevant from both modelling and policy perspectives. From the policy perspectives, our analysis is in consonance of the previous empirical literature and suggests for a more aggressive and pro-active policy actions by policy makers during high uncertainty regimes (Bloom, 2014; Pellegrino, 2017).

Rest of the chapter is structured as follows. Section 3.2 describes theoretical propositions and empirical literature on the effect of uncertainty on monetary policy effectiveness. Section 3.3 describes BMSVAR approach, followed by description of our data in section 3.4. Findings are discussed in section 3.5 and section 3.6 concludes the chapter.

3.2 Theoretical background and literature review

Oliver Blanchard, chief economist IMF wrote back in 2009, “Uncertainty is largely behind the dramatic collapse in demand. Given the uncertainty, why build new plant, or introduce new product? Better to pause until smoke clears.” Whereas, Christina Romer, the Chair of the Council of Economic Advisers, said, “Uncertainty has almost surely contributed to decline in spending.” In 2012, Christine Lagarde, Managing director, IMF said, “There is level of uncertainty which is hampering decision makers from investing and from creating jobs.” These statements, objectively show that, uncertainty plays a dynamic role to shape the real economy by affecting investment, consumption and employment. A heightened uncertainty hampers investment-decisions and optimal resource allocation needed for the economic development (Fatima and Waheed, 2011). The above explained behaviour is consistent with the observed stylised facts (Castelnuovo, Lim, and Pellegrino, 2017), that is i) Consumption and investments moves together with uncertainty but in opposite direction and ii) a jump in uncertainty leads to a severe drop in consumption and investment. Moreover, the fact that increased uncertainty has adverse impact on real aggregate variables, is also supported by a number of empirical studies (See, Alessandri and Mumtaz, 2014; Balcilar et al., 2017; Castelnuovo, Lim, and Pellegrino, 2017, among others and references there in). However, the slowdown observed in a number of economies as a result of global financial crisis of 2007, and the seminal work of Bloom (2009), rejuvenated the research examining the effect of uncertainty on the effectiveness of monetary policy.

Many theoretical explanations point to a lower effectiveness of monetary policy in presence of high uncertainty. One of the well accepted explanation is "real option theory", which works due to the fixed costs and partial irreversibility associated with investment and hiring process. The hypothesis states that, firms see their investment and hiring opportunities as a series of options and a heightened uncertainty can increase the firms' option value of delay to hire and invest (Bloom, 2014; Bloom, 2009). That is, when uncertainty is high, firms adopt 'wait and see' approach and postpone the investment and thus making the real economy less sensitive to monetary policy (Pellegrino, 2017). An analogous mechanism works in " precautionary savings approach" for consumptions. In presence of heightened uncertainty, risk averse agents may postpone their consumption (Bloom, 2014), that is a higher precautionary savings are preferred in uncertain times and hence could also be reason for the less effectiveness of monetary policy (Pellegrino, 2017). In another explanation, Bloom (2014) also argues that uncertainty may reduce effectiveness of monetary policy through productivity and risk premia channel. He argues that, when uncertainty is high, more-productive and unproductive firms are less aggressive to expand and contract their capacity respectively, thus dampening the effect of monetary policy. Further, greater uncertainty leads to increased risk premia and thus raising cost of borrowing and lessening the effect of monetary policy. Another explanation for lower effect of monetary policy in presence of increased uncertainty is based on the price setting behaviour of firms. In a general equilibrium price setting menu costs model, Vavra (2013) argues that increased uncertainty induces a frequent price changes which reduces the effectiveness of monetary policy shocks up to 50 percent relative to tranquil period (Pellegrino, 2017).[4]. Baley and Blanco (2016) by including information friction in addition to menu costs, also showed that in uncertain times, nominal shocks have significantly smaller effects on output.

There are few empirical studies, which examined the effect of uncertainty on monetary policy effectiveness. Aastveit, Natvik, and Sola (2013) by employing Interacted VAR methodology due to Towbin and Weber (2013) examined the effectiveness of monetary policy contingent to high and low uncertainty. They used different measures of uncertainty for the US economy, and conclude that, the effect of monetary policy shocks on economic activity is considerably weaker during high uncertain times. The difference in effect of monetary policy is more for GDP and investment. Further, they observe, consistent with "real-options" effects, investment responds two to five times lower to the monetary policy shocks when uncertainty is high. Moreover, they find that US uncertainty not only weakens monetary policy effects on economic activity in domestic economy, but also for Canadian economy. Pellegrino (2017), using a non-linear interacted VAR and non-linear generalised

[4]Using firm level data, (Bachmann et al., 2013), showed that firms change prices more frequently in uncertain times relative to tranquil times, a finding consistent to Vavra's (2013) model

impulse response functions due to Koop, Pesaran, and Potter (1996), examined the effect of uncertainty on monetary policy effectiveness for the US economy. They find that consistent with the "real options effects" and "precautionary savings" approach, the effect of monetary policy shocks is weaker during uncertain times. Further, they observe, the effectiveness of monetary policy shocks reduces more for GDP during uncertain times relative to tranquil times. In another study following similar methodological approach, Pellegrino (2018) examined the effect of uncertainty on monetary policy effectiveness of Euro area. They reached on similar conclusion, that the effects of monetary policy shocks are significantly lower during uncertain times relative to tranquil times. A study by Castelnuovo and Pellegrino (2016), using non-linear VAR and DSGE models, find conclusion consistent to the above studies. They observe that real effects of monetary policy shocks are substantially weaker in presence of high uncertainty.

However, these studies used different measures for uncertainty to segregate the economy into high and low uncertainty regimes and examine the effectiveness of monetary policy contingent to the high and low value of such measures. Whereas, we endogenously defined the high and low uncertainty regimes of the economy. A study by Eickmeier, Metiu, and Prieto (2016) is close to our study. By employing regime switching threshold vector auto-regression model, they examined the effect of monetary policy on economic activity during high and low volatility regimes. They conclude that monetary policy shocks have differential effect in the high and low volatility regimes. Moreover, they observe that the differential effect of monetary policy contingent to high and low volatility periods, works through balance sheet management of financial intermediaries. That is, the magnitude of differential effect of monetary policy during high and low volatility regimes, would depend on the development of financial system of an economy. The present study differs from the previous studies, as we endogenously segregated the economy into high and low uncertainty regimes using Markov-switching model. Further, we applied the regime dependent impulse response functions to find the differential effect of monetary policy shocks during high and low uncertainty regimes. Our study also contributes to the vast and growing monetary policy transmission empirical literature, which over the years has reached to a general conclusion that monetary policy affects real variables at least in shot-run (See for detailed review Christiano, Eichenbaum, and Evans, 1999; Romer and Romer, 2004; Bernanke, Boivin, and Eliasz, 2005; Mishra and Montiel, 2012; Paramanik and Kamaiah, 2014; Mohan, 2008, among others). Another, stream of literature related to our study, is the literature debating the differential effect of monetary policy contingent to the state of the economy that is expansion (good) and recession (bad) times. This is based on the fact that during recessionary period, there would be more uncertainty (See Bloom, 2014, for details). There seems to be an agreement that monetary policy shocks are less effective during recessionary periods from the vast literature.

3.3 Methodology

The development of MSVAR (Markov switching vector auto-regression) models allowed macroeconomists to accommodate one of the important challenges that is structural change or regime shifts in the macroeconomic modelling.[5] The origin of the MSVAR approach may be traced to Goldfeld and Quandt (1973), in form of

[5]See Granger (1996), Hansen (2001), Perron (2006) for the importance of structural or regime shifts in macro-modelling

switching regressions. Later, Hamilton (1989) and Krolzig (1998) made important contributions respectively to develop univariate and multivariate MSVAR. The MSVAR model is well equipped to characterise the macroeconomic variables in presence of structural breaks or regime shifts. The Markov switching model falls into the category of non-linear models as it captures the non-linear dynamic properties of the variables such as asymmetric and time varying cycles, breaks or jumps in the variables (Fan and Yao, 2005; Balcilar et al., 2017). To fulfil the main goal of the present study that is examining the effectiveness of monetary policy shocks during high and low uncertainty regimes, MSVAR is therefore an appropriate modelling approach.

3.3.1 Markov Switching Vector Autoregression (MS-VAR) model

The MS(m)-VAR(p) model for K endogenous variables X_t may be represented in Equation 3.1 as follows

$$X_t = \left\{ \begin{array}{ll} \alpha_1 + \beta_{11} X_{t-1} + \cdots + \beta_{p1} X_{t-p} + A_1 \nu_t & \text{if} \quad s_t = 1 \\ \vdots & \\ \alpha_m + \beta_{1m} X_{t-1} + \cdots + \beta_{pm} X_{t-p} + A_m \nu_t & \text{if} \quad s_t = m \end{array} \right\} \tag{3.1}$$
$$\nu_t \sim N(0; I_k)$$

Here, variables of the vector X_t are explained by the intercepts α_i, autoregressive terms of order p and residuals $A_i \nu_t$. This is a general framework, where in either or some specific parameters may be allowed to switch between the m regimes.[6] ν_t is a K dimensional vector of normally distributed standard residuals with *zero* mean. The variance of the standard residuals are normalised to unity. However,

[6]See Krolzig (1997) for special cases and their properties

the vector ν_t is pre-multiplied by matrix A_i, which is regime dependent. Thus, the variance-covariance matrix $\sum_i$ of the residuals $A_i \nu_t$ are also regime dependent; represented as follows

$$\sum_i = E\left(A_i \nu_t \nu_t^{'} A_i^{'}\right) = A_i E\left(\nu_t \nu_t^{'}\right) A_i^{'} = A_i I_K A_i^{'} = A_i A_i^{'} \tag{3.2}$$

S_t a regime variable is unobserved, independent of past X_s and, conditional on S_{t-1}, assumed to follow a hidden Markov process that is

$$Pr\left(S_t = j | S_{t-1} = i\right) = p_{ij}$$

for all t and regimes $i, j = 1, 2, 3, \cdots, m$. For, m regime, S_t follows a m-state Markov process with following transition provability matrix

$$P = \begin{bmatrix} p_{11} & p_{12} & \cdots & p_{1m} \\ p_{21} & p_{22} & \cdots & p_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ p_{m1} & p_{m2} & \cdots & p_{mm} \end{bmatrix} \tag{3.3}$$

P_{ij} is the probability of the economy for being in regime j at time t, given that at time $t-1$, the economy was in regime i, where $i, j \in \{1, 2, \cdots, m\}$.

The MSVAR specified in equations 3.1-3.3 is a general framework. Our methodology is based on the above framework, where X_t includes $\{OG_t, INF_t, IR_t\}$[7]. Given our objective, all parameters of the model including variance matrix $\sum_i$ are allowed to switch according to the latent regime variable

[7]Description of the Data is given in section 3.4

S_t. Here, variation in parameters directly reflects regime switching. Thus, regime changes treated as random events are governed by exogenous Markov process. The probability value P_{ij} associated with latent Markov process based on the sample information determines the state of the economy. That is, inference about the regime can be made on the basis of the estimated probability for each observation that it is coming from a particular regime. For our study, we assume that $m = 2$ that is two regimes. Studies by Diebold, Lee, and Weinbach (1994) and Filardo and Gordon (1998) among others show that two regime markov switching model sufficiently captures the behaviour of the macroeconomic variables. Two regime are consistent with the notion of crisis-recovery or recession-expansion periods for an economy and for high and low uncertainty regimes. We adopt Bayesian Markov-Chain Monte Carlo (MCMC) integration method of Gibbs sampling for estimation. This approach allows for regime dependent impulse (RDI) response analysis and also allows to calculate the possible confidence intervals of the RDI responses.

The MS-VAR model specified in equations 3.1-3.3 has many interesting features to analyse the dynamic relation among the study variables. First, classification of regimes based on the parameter switching in the full sample is possible and therefore, changes in the dynamic interactions among the variables are recognised. Second, dynamic changes in the relationship among the variables are allowed to change at any unknown time. Third, inferences about the regime dependent impact of a particular variable on other variables of the system is possible through regime dependent impulse response functions.

3.3.2 Estimation

For estimating the parameters of a Markov Switching model, three methods namely maximum likelihood (ML), expectation maximization (EM) algorithm and Bayesian MCMC estimation approach based on Gibbs sampling are commonly used. One of the simplest estimation method for MS models is ML. However, it may be computationally demanding and there would be slow convergence(Balcilar et al., 2017)[8]. Whereas, EM algorithm is commonly used method for estimation of MS models. This method follows a two step procedure. In first step, it computes the conditional expectation of log likelihood, conditioned to the specified current parameter estimates and the data known as E-step. While, parameters are computed based on the maximisation of log likelihood of the complete data in the second step, known as M-step. However, standard errors of the parameters from EM algorithm directly cannot be obtained. Moreover, EM algorithm may have slow convergence (Balcilar et al., 2017). The third method for estimation of parameters of MS models is Bayesian MCMC based on Gibbs sampling. We have used the last method for estimation that is Bayesian MCMC method. The Bayesian MCMC estimation approach assumes one sample path for the regimes and therefore does not face the problem like ML and EM methods (See Balcilar et al., 2017). We follow Balcilar et al. (2017) to implement the bayesian MCMC estimation approach and adopt following steps

a) Draw the parameters given the regimes

b) Draw the regimes given transitional probabilities and parameters of the model.

[8] For review of ML method see Redner and Walker (1984)

c) Draw the transitional probabilities given regimes. Here we do not include model parameters like excluding transition probabilities in first step.

d) Draw $\sum_i$, given regimes, transitional probabilities and parameters using a hierarchical prior.

In second step above, we put a threshold level for a draw to be accepted that is at least 5 percent of the observations must fall in the regimes associated with the particular draw. In step (c), we use Dirichlet distribution to draw unconditional probabilities P, given the regimes. We set the priors for the Dirichlet distribution as 80 and 20 percent probability respectively of staying in the same regime and switching to the other regime. We perform the MCMC integration with 60,000 posterior draws with a 30,000 burn-in draws.

3.3.3 Regime dependent impulse response function

One major attraction of the VAR modelling has been it's ability to analyse the dynamic interactions among the variables through impulse response functions (IRF). Moreover, for non-linear models like Markov Switching-VAR, it is difficult to interpret the dynamic interactions of the variables only through parameters. However, for non-linear models, computation of IRF is complicated in comparison of a linear VAR. As, the IRF in MS-VAR model depend on the regime of the system in every time period t and there is no simple method to compute the future path of the regime process (Balcilar et al., 2017).

We follow Ehrmann, Ellison, and Valla (2003) to construct regime-dependent impulse response function (RDIRF), assuming regimes do not switch beyond the shock horizon. The RDIRF traces the expected path of the endogenous variable at time $t+h$ following a shock of given size (say one standard deviation) to the k^{th} standard disturbance at time t condition to regime i. The RDIRF can be defined as in equation for regime i.

$$\frac{\partial E_t X_{t+h}}{\partial \nu_{k,t}} | s_t = \cdots = s_{t+h} = i = \theta_{ki,h} \text{ for } h \geq 0 \tag{3.4}$$

Where $\theta_{ki,h} = \{\theta_{ki,1}, \theta_{ki,2}, \cdots, \theta_{ki,m}\}$ is the vector of the responses of the endogenous variables to a specific shock conditional to regime i. $\nu_{k,t}$ is the structural shock to the kth variable.

However, within MS-VAR framework, we can estimate variance-covariance matrix $\sum_i$, but not the matrix A_i for all $i \in \{1, 2, \cdots, m\}$. This leads to the well known problem of identification. One of the possible way to identify the matrix A_i is to impose the sufficient restrictions on the parameters obtained from reduced VAR. We follow Sims's (1980) recursive identification scheme, which is based on the cholesky decomposition of the variance-covariance matrix $\sum_i$. The order of the variables are $\{OG_t, INF_t, IR_t\}$.

3.4 Data

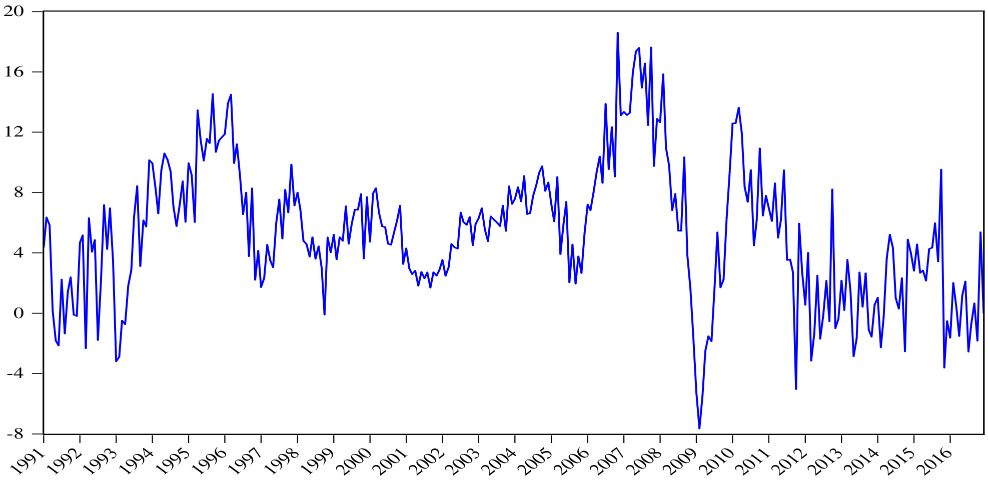
We have used Index of Industrial Production (IIP), Wholesale Price Index (WPI) and Weighted Call Money Rate (WCMR) of monthly frequency. The data has been obtained from the EPW time series database for the period April 1991 to December 2016. The choice of the sample period is justified by the fact that prior to 1990s, monetary policy was subjected to financial repression and fiscal dominance (Ghate and Kletzer, 2016). In fact, during 1951-1970 and 1971-90, monetary policy was guided by the plan financing and credit planning respectively. Only after the the implementation of structural reform and financial liberalisation in 1990s, monetary policy became market oriented (Mohanty, 2013). IIP and WPI have been seasonally adjusted as the tests exhibit presence of seasonal effect, using X-13 ARIMA-SEATS of U.S. Census Bureau[9]. We transformed the IIP and WPI data following Equations 3.5-3.6. The growth rate of IIP and WPI in percentage terms are used as the proxies for output growth and inflation respectively.

$$y_t = 100 * \ln(iip_t/iip_{t-1}) \tag{3.5}$$

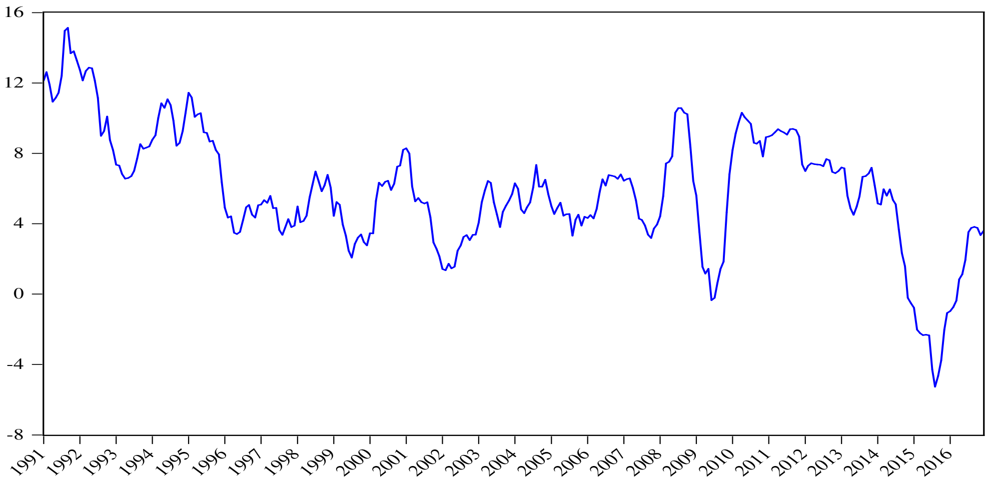
$$\pi_t = 100 * \ln(wpi_t/wpi_{t-1}) \tag{3.6}$$

During the sample period, there have been many changes in the monetary policy framework of RBI, from monetary targeting changed to multiple indicators approach and recently resorted to flexible inflation targeting (Bhoi, Mitra, and Singh, 2017). The changes in the monetary policy framework creates a challenge to select an appropriate variable as monetary policy variable. Following literature, where WCMR has been frequently used as the policy variable, we also chose WCMR as the indicator of policy variable. Moreover, Bhoi, Mitra, and Singh (2017) through two different approaches also show that WCMR is most appropriate variable. The selected variables output growth (growth of IIP), Inflation (Growth of WPI) and Interest rate (WCMR) are henceforth represented as OG, INF and IR respectively.

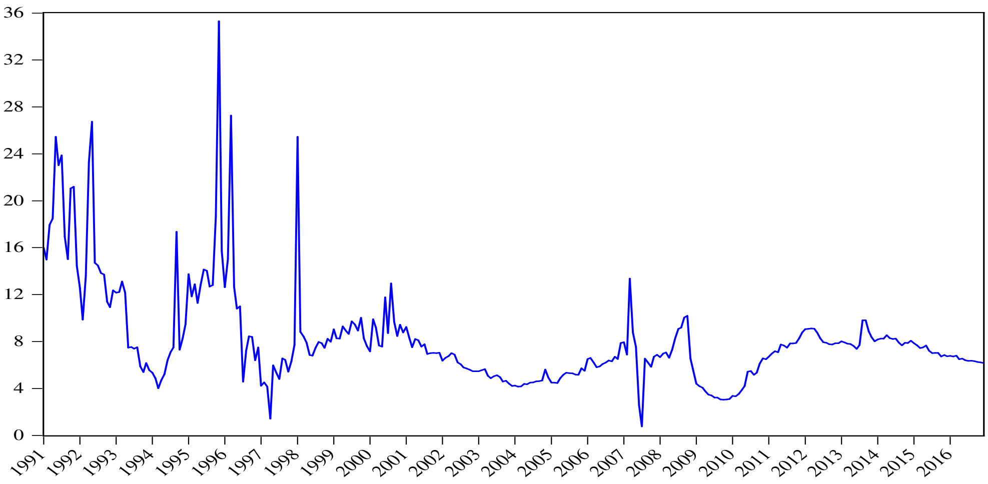
[9]Results for the seasonal effects are presented in Table 3.A.1. There is no seasonal effect in WCMR



(a) Output Growth



(b) Inflation



(c) Interest Rate (WCMR)

Figure 3.1. Time-series plots of Variables

3.5 Empirical Findings and Discussions

Before estimating our MSVAR model, we discuss some basic descriptive statistics time series properties of study variables that is output growth (OG), Inflation (INF) and Interest Rate (IR) and model selection and estimation strategy employed.

3.5.1 Summary Statistics

The summary statistics and time series plots of the variables are presented in Table 3.1 and Figure 3.1 respectively. The average output growth and inflation over the

Table 3.1. Descriptive Statistics

Variables/Statistics	OG	INF	IR
Mean	5.306	5.885	8.176
Prob.(Mean=0)	0.000	0.000	0.000
SD	4.525	3.439	4.339
Minimun	-7.648	-5.263	0.762
Maximum	18.594	15.133	35.313
Skewness	0.186	-0.231	2.516
Kurtosis	0.179	0.663	8.900
JB	2.212	8.488	1358.923
Prob.(JB=0)	0.331	0.014	0.000
LB(Q1)	186.217	299.180	183.170
Prob	0.000	0.000	0.000
LB(Q4)	634.722	1028.227	576.931
Prob	0.000	0.000	0.000
ARCH(1)	181.371	291.045	101.989
Prob	0.000	0.000	0.000
ARCH(4)	208.958	290.506	128.941
Prob	0.000	0.000	0.000
CV	1.964	1.418	1.517

Notes: SD and CV denote standard and coefficient of variation, respectively. JB denotes Jarque-bera test for normality. LB(Q1) and LB(Q4) refer Ljung-Box q-statistics for autocorrelation tests at lag one and lag four respectively. While ARCH(1) and ARCH(4) reports LM tests for the autoregressive conditional heteroscedasticity (ARCH) at lag one and lag four respectively.

sample period is about 5 and 6 percent respectively, whereas average interest rate is more than 6 percent. The Jarque-Bera tests show inflation and interest rate follow non-normal distribution, however output growth is normally distributed. The results of the Ljung-Box tests for autocorrelation at lag one[LB(Q1)] and four [LB(Q4)] of all variables reveal presence of autocorrelation with their respective lags. The LM statistics for autorgressive conditional heteroscedasticity (ARCH) at lag one [ARCH(1)] and four [ARCH(4)] show that the variance of the variables are time varying. The coefficient of variation (COV) statistics, show that the output growth is relatively more volatile than inflation and interest rate. Figure 3.1, reveals that after opening up the economy in 1991, there have been more or less upward trend in the output growth but with fluctuations. The impact of Asian crisis of 1997 can be observed from the Figure, after which there have been a stable performance till the Global financial crises (GFC) 2007. The impact of GFC is quite visible in 2009-10. After GFC, the output growth has been more volatile. For the inflation, we observe a gradual decrease in level as well in volatility. Though during 2002 to 2014, the persistent behaviour of inflation can be observed except low inflation during 2009-10. High inflation during 1991-92 may be attributed to the drought and large fiscal deficit of government and during 2008, inflation was fuelled by the high global commodity prices and credit expansion.[10]. Despite a rising policy rate, during 2010, inflation was rising due to the high global commodity prices after GFC.[11]. One interesting fact about the interest rate is that there has been a fluctuation in the policy rate, whenever, there is a shock in the economy for example balance of payment crises in 1991, Asian crisis in 1997, Dot.com bubble in 2000-2001 and GFC in 2007-08. One common observation about output growth and inflation is that both has become more stable over the study period (Mohanty, 2010).

[10]See Mohanty for detailed events related to inflation

[11]This points also highlights the effect of external factors

3.5.2 Time series Properties

To examine the stationarity property of the variables, we used the battery of unit root tests. Results are reported in Tables 3.2-3.3. Tests are performed with two alternative specifications. In first specification, we include only constant in the test equation, while another specification includes both constant and trend in the test equation. Results of unit root tests show that output growth is stationary except DF-GLS test, with constant and trend specification. For, inflation ADF, DF-GLS and Ng and Perron (2001) test results exhibit presence of unit root opposite to the conclusion of other tests. The result showing the presence of unit root is counter intuitive as mostly macro-variables like inflation found to be stationary. Similarly, the KPSS and Ng and Perron (2001) test results for the interest rate show the presence of unit root. However, variation in the results may be due to the presence of structural break(s) in the variables. Perron (1989) pointed that unaccounted breaks in data generation process may reduce power of tests and results may be misleading. Therefore, in presence of structural breaks in the stationary variables, unit root tests not accounting for structural break(s) may incorrectly show non-stationarity property in the variables.

To overcome the above stated issue, we used Zivot and Andrews (1992) and Lee and Strazicich (2003) unit root tests. Both these tests accommodate the structural breaks in the data generation process. ZA test assumes one break, while LS assumes two structural breaks and in both tests, breaks are endogenously determined. Table 3.4 reports the results of both ZA and LS unit root tests. The results of both tests for all variables reveal that variables are stationary with structural breaks at different dates.

Table 3.2. Unit Root Tests

Tests/ Variables		Test Statistics			Critical Values		
		OG	INF	IR	1%	5%	10%
ADF	C	-3.354	-2.244	-3.505	-3.454	-2.871	-2.572
	C+T	-3.605	-2.283	-3.722	-3.992	-3.426	-3.136
DFGLS	C	-2.554	-0.385	-1.895	-2.573	-1.942	-1.616
	C+T	-2.601	-1.927	-2.964	-3.470	-2.910	-2.606
PP	C	-6.968	-3.143	-6.638	-3.45121	-2.871	-2.572
	C+T	-7.139	-3.382	-7.920	-3.988	-3.424	-3.135
KPSS	C	0.277	0.607	0.860	0.739	0.463	0.347
	C+T	0.169	0.179	0.255	0.216	0.146	0.119

Notes: C and $C+T$ refer two alternative specifications, with constant and with constant and a linear trend in test equations respectively. ADF is the Augmented Dickey-Fuller test (Dickey and Fuller, 1979), DFGLS is the augmented Dickey-Fuller test (Elliott, Rothenberg, and Stock, 1992) with generalised least squares de-trending, PP is the Phillips-Perron test (Phillips and Perron, 1988) and KPSS is the Kwiatkowski et al. (1992a) stationary test. Lag lengths for ADF and DFGLS tests are selected using Bayesian Information Criterion (BIC). For the PP and KPSS tests bandwidths are based on Newey-West automatic selection.

3.5.3 Selection and Estimation of MSVAR Model

We applied Markov Switching model to take account of regime changes (high and low uncertainty) and structural breaks in the relationship among the study variables.

Table 3.5 reports model selection criteria and estimates of MSVAR. We used the lag order chosen in case of linear VAR that is two ($p = 2$). The number of regimes ($m = 2$) and variance specification may differ for alternative MSVAR specifications. We chose $m = 2$ that is two regimes using Akaiki information criterion (AIC) as suggested by Krolzig (1997) and Psaradakis and Spagnolo (2003). We estimate the specified MS(2)VAR model using the Bayesian MCMC method utilising the Gibbs sampling.

Table 3.3. Ng-Perron Unit Root Tests

Variables/ Statistics	Constant			
	MZ_α	MZ_t	MSB	MPT
OG	-16.149	-2.802	0.174	1.667
INF	-1.065	-0.563	0.529	16.515
IR	-3.740	-1.270	0.340	6.609
Level of Sig	Critical Values			
1%	-13.800	-2.580	0.174	1.780
5%	-8.100	-1.980	0.233	3.170
10%	-5.700	-1.620	0.275	4.450
Variables/Statistics	Constant and trend			
	MZ_α	MZ_t	MSB	MPT
OG	-16.687	-2.857	0.171	5.656
INF	-7.896	-1.973	0.250	11.582
IR	-15.772	-2.792	0.177	5.879
Level of Sig	Critical Values			
1%	-23.800	-3.420	0.143	4.030
5%	-17.300	-2.910	0.168	5.480
10%	-14.200	-2.620	0.185	6.670

Notes: The lag length or the bandwidth for the MZ_α, MZ_t, MSB and MPT tests are based on the modified Bayesian Information Criterion of Ng-Perron (2001)

3.5.4 Regime Identification and Properties

First, we discuss the relevance of identified regimes by the MSVAR model employed in the study. The smoothed probability of regime one (Low uncertainty) and regime two (high uncertainty) are shown in Figures 3.1-3.2 respectively. In Figure 3.2, we can observe that high uncertainty regime (regime two) has frequently occurred in beginning of study period relative to later phase. It is also worthy to note that, the high uncertainty regime (regime two) coincides with the different crises and shocks observed in the economy. High uncertainty regime observed during 1991-92 coincides with balance of payment crisis(1991), while the period 1995-97 of regime 2 coincides with the Asian financial crisis (1997), high inflation due to shortfall in production,

Table 3.4. Unit Root Tests with Structural Breaks

Variables	ZA test			LS unit Root test		
	Statistics	P-value	Break Date	Statistics	Break Dates	
OG	-4.882	0.004	2005:12	-5.593*	1996:03	2006:09
INF	-3.734	0.000	2010:09	-4.391**	2003:07	2014:07
IR	-4.488	0.000	1996:04	-5.536*	1996:02	1998:11

Notes: ZA and LS tests are the endogenous structural break unit root tests due to Zivot and Andrews (1992) and Lee and Strazicich (2003) respectively with breaks in both intercepts and linear trend. For the ZA test lag order is selected using BIC. While for the LS test lag length is based on the general to specific approach using 10% significance level. * and ** denote level of significance of 1% and 5% respectively.

Table 3.5. Model selection criteria

	MS(2)-VAR		Linear VAR(2)
Log Liklihood			-1814.609
AIC criterion	7.810		13.542
BIC criterion	8.369		13.759
HQ criterion	8.031		13.629
log(FPE)	7.812		13.542
Transition Probability	**P**	**0.922**	**0.086**
		0.078	**0.914**
Regime Properties	Probabilityl	Observations	Duration(Months)
Regime 1	0.722	225	12.84
Regime 2	0.278	87	11.68

large fiscal deficit and monetary expansion during 1994-95. The dot.com bubble (2000) and GFC(2007) also falls in region observed in high uncertainty regime.

Further, we plot high uncertainty regime (regime two) overlaying on output growth, inflation and interest rates as shown in Figures 3.4-3.5 respectively. These figures quite clearly exhibit that our specified model MSVAR identifies two regimes that is of low and high uncertainty based on the volatility and shocks of output growth, or of inflation, or of interest rate or all of these. We observe that low uncertainty regime (regime one) and high uncertainty regime (regime two) are associated with high and low output growth respectively. Thus from the above observations, we may conclude that results suggest two distinct regimes, regime one associated with low uncertainty and high output growth and regime two, associated with high uncertainty and low output growth.

The transition probabilities shown in Table 3.5 reveal that both regime one and two are of persistent nature. Assuming that, the economy was in regime one at time t, the likelihood for the economy to remain in the same regime that is in regime one at time $t + 1$ is 0.922. Similarly, the probability for the economy being in regime two at time $t + 1$, assuming that economy was in regime two at time t is 0.914. The long-run average probability for the regime one that is low uncertainty and high output growth is 0.722, while for the regime two that is for high uncertainty and low output growth regime is 0.278. Furthermore, low(high) uncertainty- high(low) output growth regime found to have high correlation with expansion(recession) periods (See Bloom, 2014, among others) and also it is generally accepted that the probability for recessionary periods should be lesser than expansionary periods (Du Plessis, 2006). Our results suggests that on average expected duration of the low uncertainty-high output growth regime (regime one) is 12.84 months and 11.68 months for the high uncertainty-low output growth regime (regime two). After identifying the regimes and it's appropriateness we move to discuss the effect of monetary policy contingent to the two different regimes.

3.5.5 Impulse Response Functions

We analyse the results of our empirical exercise using the regime dependent impulse response function (RDIRF) due to Ehrmann, Ellison, and Valla (2003). Making inference with economic reasoning on the basis of autoregressive coefficients of MSVAR model is difficult and might be misleading. As the model is essentially an *atheoretical* representation of the dynamic relationship among the endogenous variables. The results of impulse response shown in Figures 3.6 are obtained from the MSVAR model specified in equations 3.1-3.3. The Figure reports impulse response with 95% confidence interval for the response of endogenous variables to the shock given to monetary policy variable that is interest rate. It is to be noted that, identification of the MSVAR model specified in equations 3.1-3.3 is obtained through cholesky decomposition. Orthogonalisation of the original residuals in cholesky decomposition, depends on how the variables of the model are ordered, in result it also affects impulse response. The impulse response shown in Figure 3.6 are based on the "Output growth(OG)","Inflation (INF)","Interest Rate(IR)" ordering. The ordering determines the level of exogeneity of the variable (Bhoi, Mitra, and Singh, 2017), we assumed that "output growth" to be most exogenous. Moreover, in countries like India, generally policy makers react with a lag. Figure 3.6 shows regime dependent impulse response of output growth and inflation to one standard

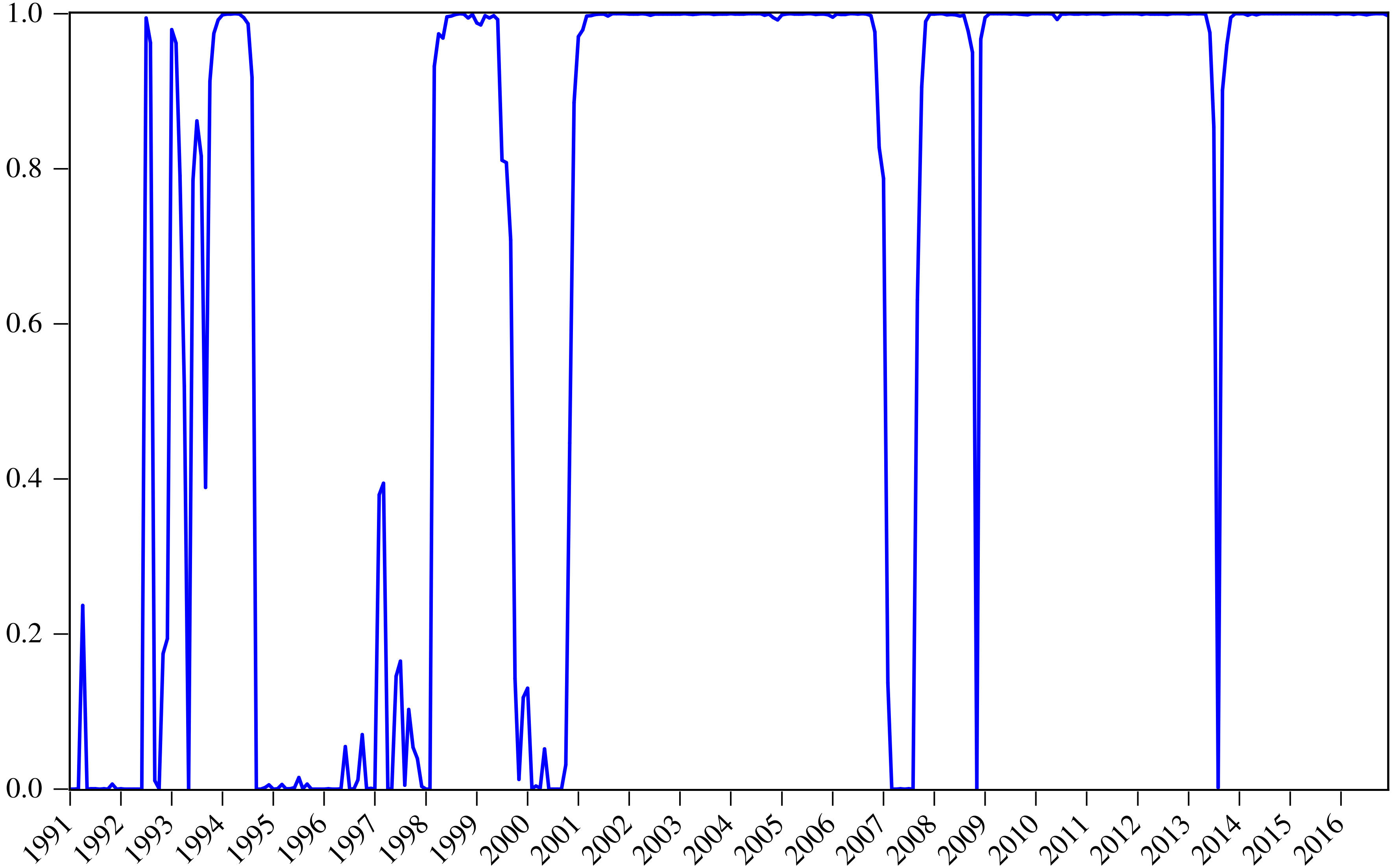


Figure 3.1. Smoothed probability of low uncertainty regime(Regime 1)

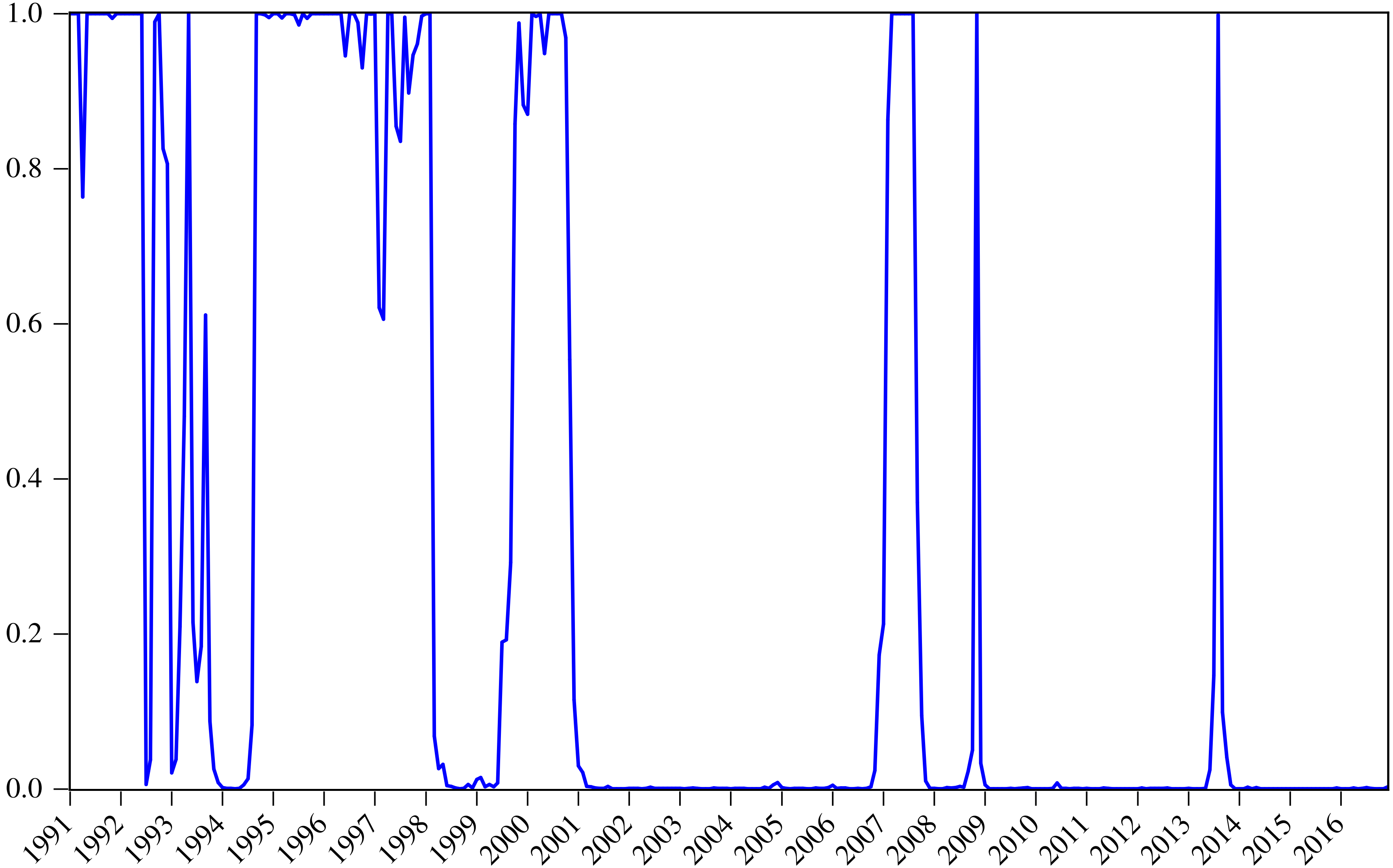


Figure 3.2. Smoothed probability of high uncertainty regime (regime 2)

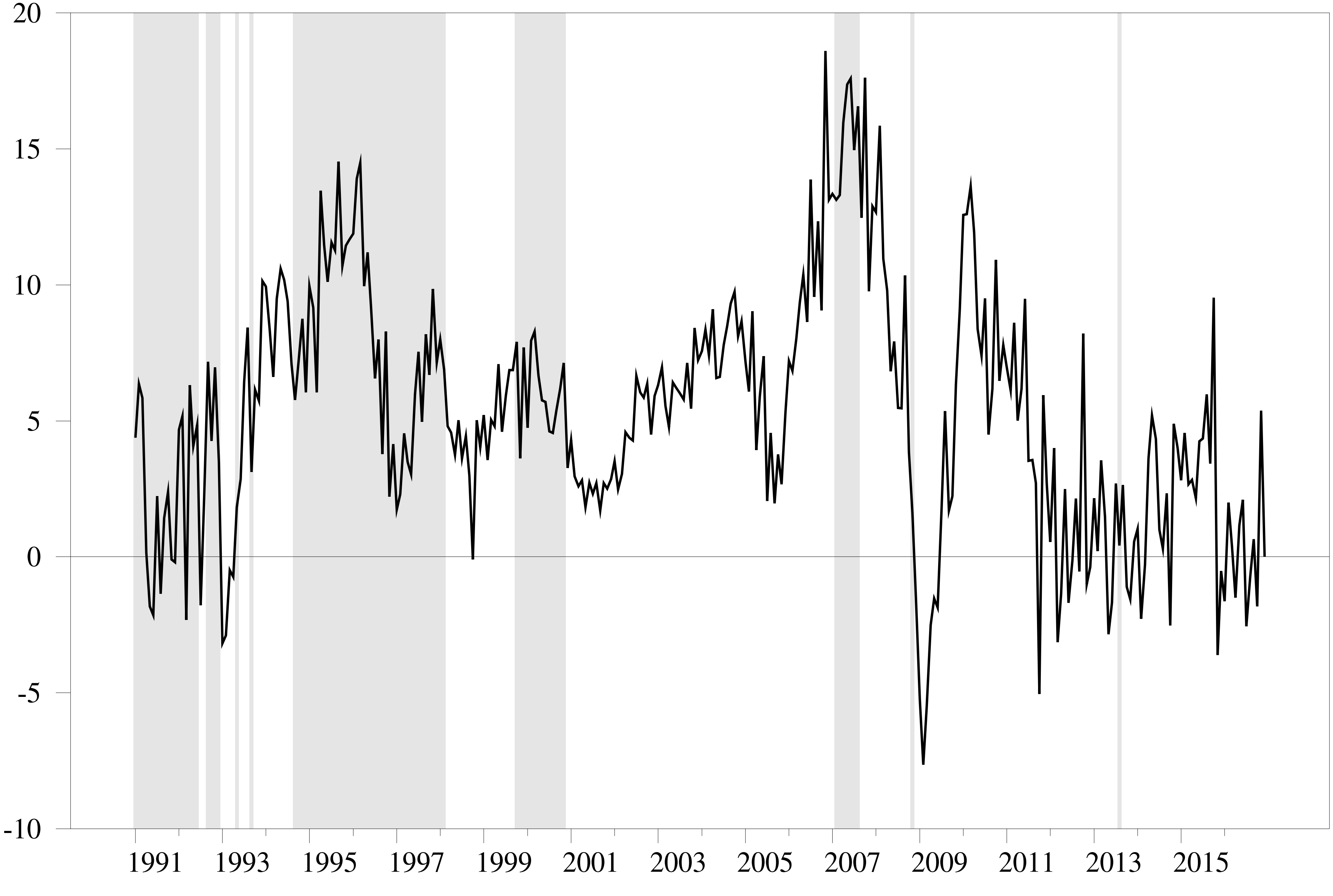


Figure 3.3. Output Growth and Smoothed Probability of Regime 2

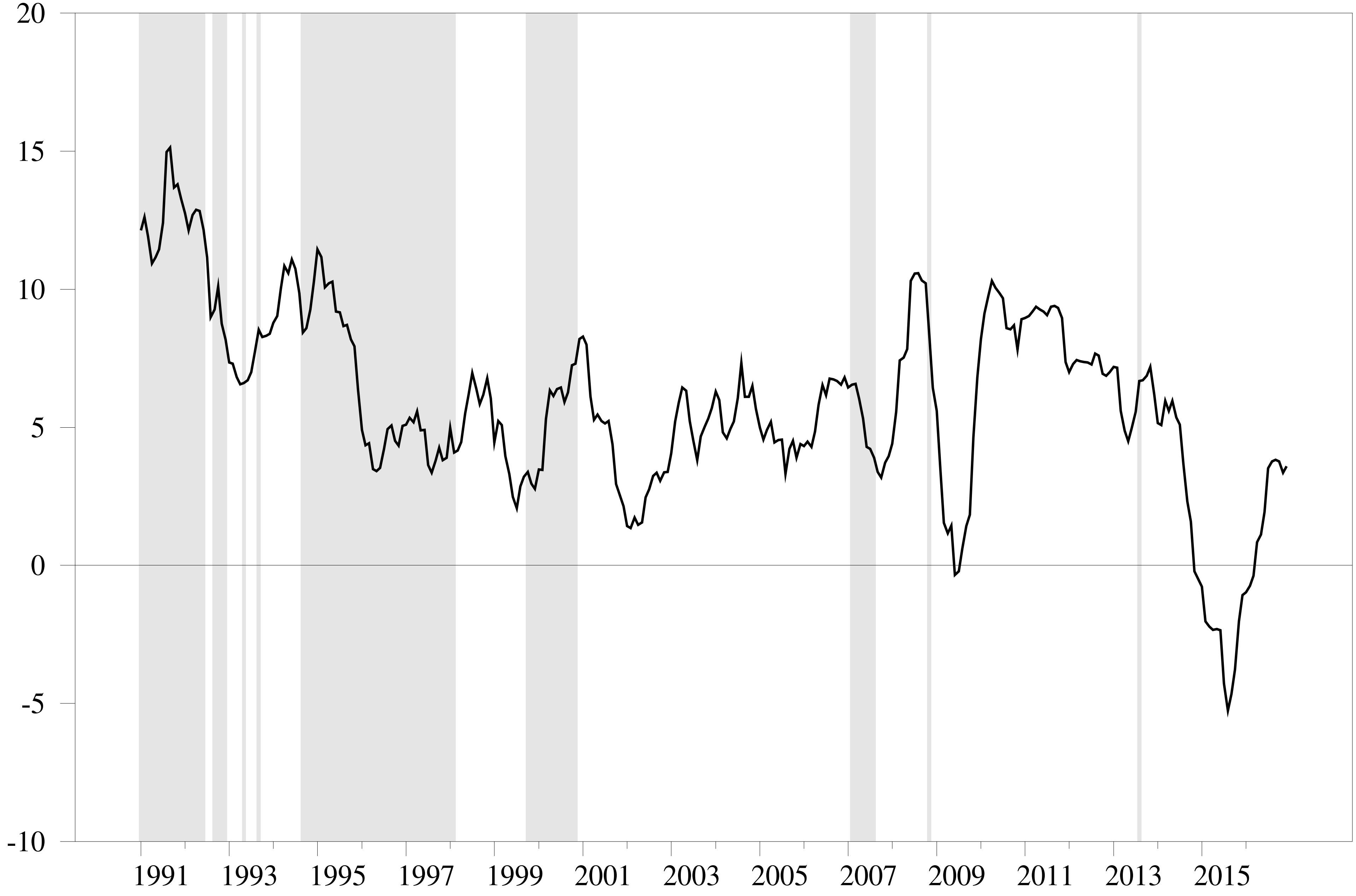


Figure 3.4. Inflation and Smoothed Probability of Regime 2

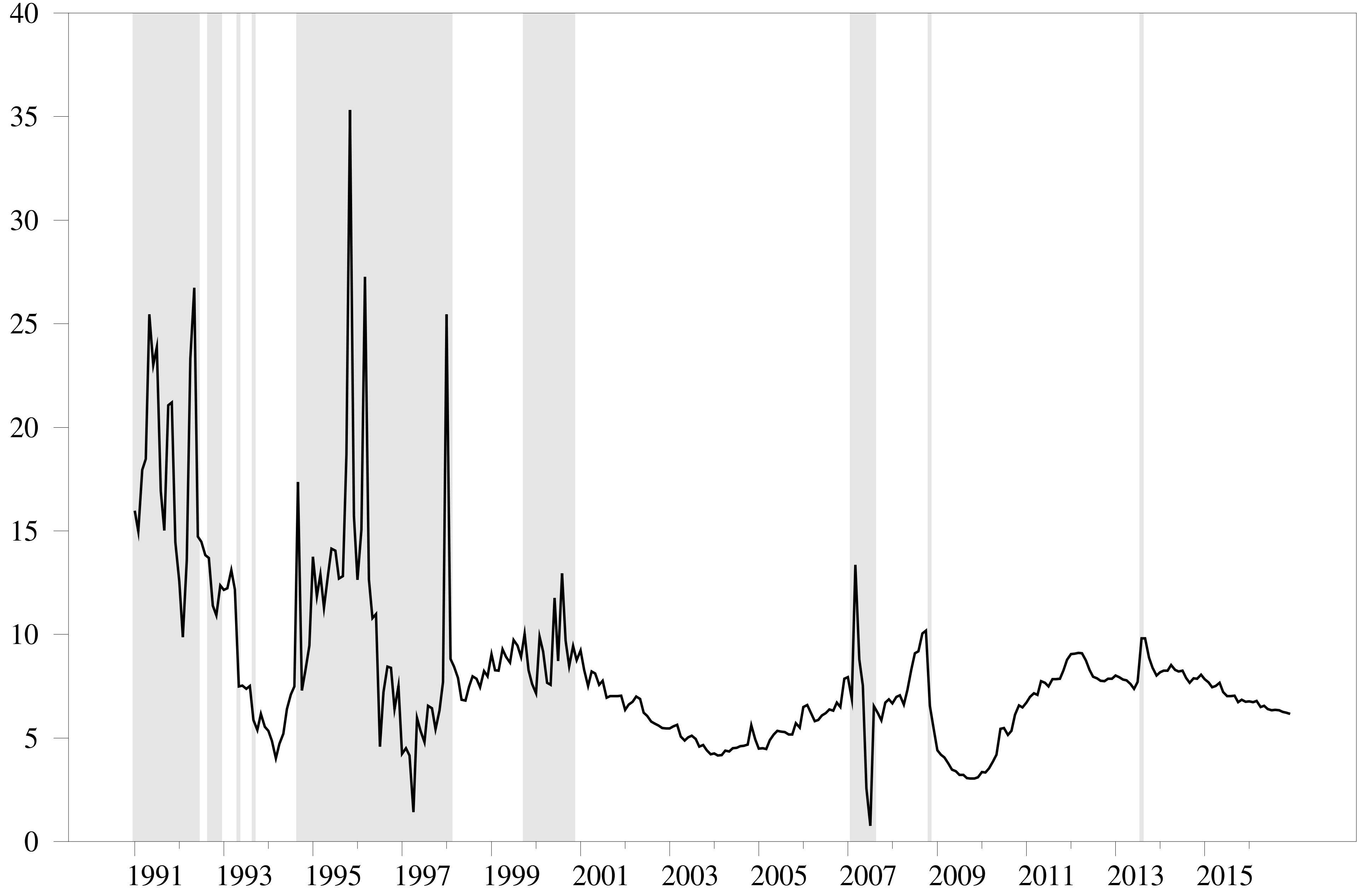


Figure 3.5. Interest Rate (WCMR) and Smoothed Probability of Regime 2

deviation positive shock to interest rate, an indicator of monetary policy over a horizon of 36 months for both low and high uncertainty regimes.

We see that, the responses of output growth and inflation facing a positive shock in monetary policy(tight monetary policy) are significant and in line with the conventional economic theory in both regimes. However, in high uncertainty regime responses are less compared to the responses in low uncertainty regime. Output growth falls by at most by approximately 0.61% in low uncertainty regime, while in high uncertainty regime it falls by at most approximately 0.30%. In both the regimes, however the effects become zero after about 36 months following the shock.

A similar pattern is observed for the response of inflation following the shock in monetary policy. However, the difference between the peak response of inflation in low and high uncertainty regimes is less than output growth. Inflation falls by at most 0.46 percent in low uncertainty regime following the shock in monetary policy, while in high uncertainty regime, the peak response of inflation is at most a fall by 0.31 percent.

The results are in line with general conclusion that uncertainty dampens the effect of monetary policy (See Bloom, 2014; Aastveit, Natvik, and Sola, 2013; Pellegrino, 2018). The differential response or state-dependent effectiveness of monetary policy could be explained by the proposition of real options value theory (Bloom, 2009; Bloom et al., 2012). The real option effects could be the result of fixed cost and / or partial irreversibility (Pindyck, 1991). During high uncertainty phase, since the real options value of waiting increases, "wait and see" behaviour becomes norm of firms. As a result firms becomes unresponsive to changes in interest rate (Bloom, 2009; Bloom et al., 2012). On the other hand, in low uncertainty phase, the response will be larger as firms are more reactive to changes in factor prices (Caggiano, Castelnuovo, and Nodari, 2017).

Through price adjustment mechanism, Vavra (2013) also shows that during high uncertainty period, monetary policy shocks are less effective. Despite price adjustment costs, in high uncertainty phase , firms frequently adjust their prices. This frequent price adjustment results in higher aggregate price flexibility, which reduces the effect of monetary policy shocks.

Moreover, the high correlation between recessionary period and high uncertainty regime, aslo validates the explanation given by Berger and Vavra (2015). With in the partial and general equilibrium models, and focussing on aggregate durable expenditure authors show that during recession macroeconomic policies are less effective.

Overall, our empirical results with the relevant theoretical explanation show that, the effect of monetary policy is sensitive to the regime prevailing in the economy.

3.6 Conclusion and Policy Recommendations

There is a growing body of literature examining the effectiveness of monetary policy on the macroeconomy in different contexts for developed and developing countries. However, lately, especially after the GFC, the focus of research shifted to examine the role of uncertainty in economic activity and on the monetary policy effectiveness. There are ample empirical studies, which found evidence that uncertainty affects economic activity. Further, a number of theoretical studies like Bernanke (1983), Dixit and Pindyck (1994), Bloom (2009) and Bloom (2014), Aastveit, Natvik, and Sola (2013), Vavra (2013) suggest that uncertainty does influence the monetary

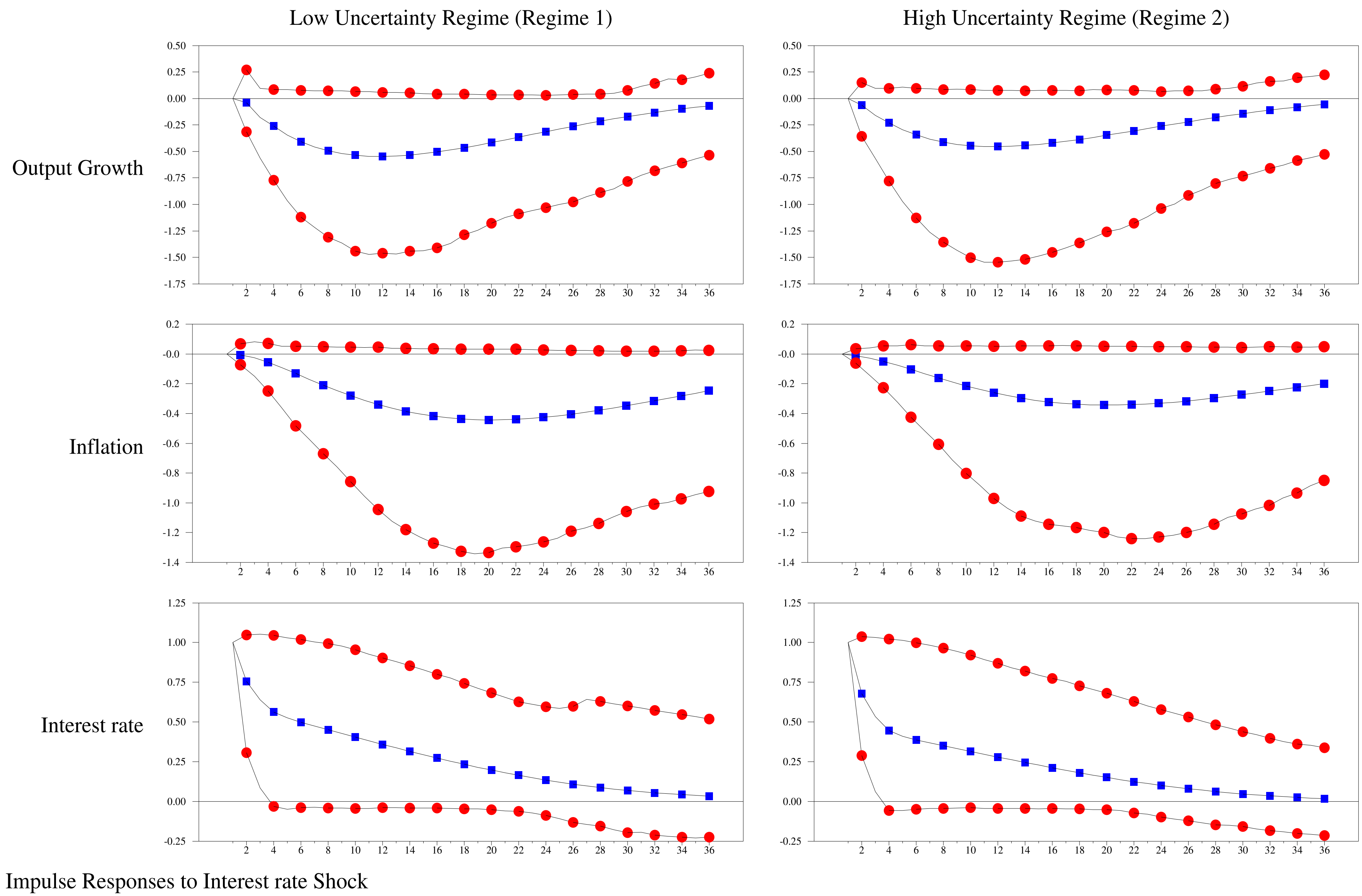


Figure 3.6. Impulse Response to interest Shock

policy effectiveness. A number of empirical studies show that heightened uncertainty dampens the effectiveness of monetary policy. However, till now empirical studies are restricted to only developed countries.

To this end, the present study examines the influence of uncertainty on monetary policy effectiveness for a developing country namely India using the monthly data on output growth, inflation and interest rate for the period April 1991 to December 2016. We applied a non-linear VAR, which allows us to examine the effect of monetary policy shocks during high and low uncertainty periods. The results exhibit that, uncertainty influences effectiveness of monetary policy shocks. We find weaker effects of the monetary policy shocks during high uncertainty regime relative to low uncertainty regime. More specifically, we find that an increase in interest rate (tight monetary policy) leads to a fall of output growth in high uncertainty regime by about half of the fall in output growth, when uncertainty is low. A similar pattern of effects of tight monetary policy is observed for inflation as well. Overall the results are in line with the theoretical propositions that uncertainty dampens the effectiveness of monetary policy shocks.

The findings have a number of relevant policy implications. Policy should be framed to avoid "wait and see" attitude among the agents such as by creating incentives to spend and invest. Incentives may be in the form of tax rates or interest rates. The influence of uncertainty on the effectiveness of monetary policy shocks could also be lessened by implementing more aggressive policies during high uncertainty regime like by reducing nominal short-term interest rate or resorting to "quantitative easing". Moreover, there should be clear policy communications to reduce systemic risk and hence increase the effectiveness of monetary policy. Finally, the findings suggest for a state-dependent policy response, that is to implement different policy stances in high and low uncertainty regimes.

Appendix

3.A Tables

Table 3.A.1. Seasonality Tests

Variables	Tests	Statistics	DF
IIP	BM	139.762*	11
	NT	212.700*	11
	MV	3.358*	24
WPI	BM	49.137*	11
	NT	212.749*	11
	MV	5.479*	24
WCMR	BM	2.12	11
	NT	5.064	11
	MV	1.981	24

Notes: BM refers between months test for the presence of seasonality assuming stability.NT refers non-parametric (Kruskal-Wallis) test of seasonality assuming stability. MV refers moving seasonality test. * indicates significance at 1 % or better.

3.B Figures

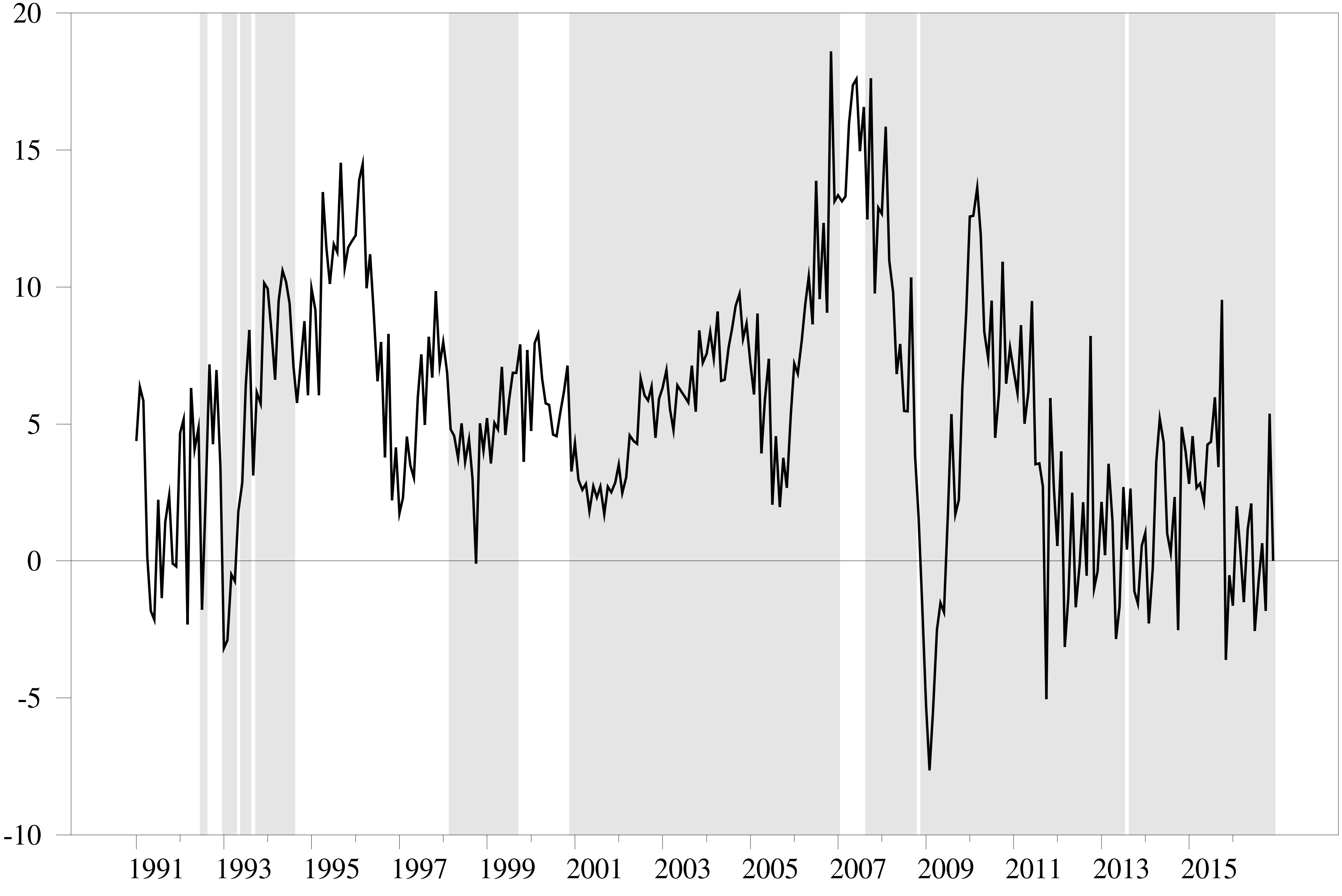


Figure 3.B.1. Output Growth and Smoothed Probability of Regime 1

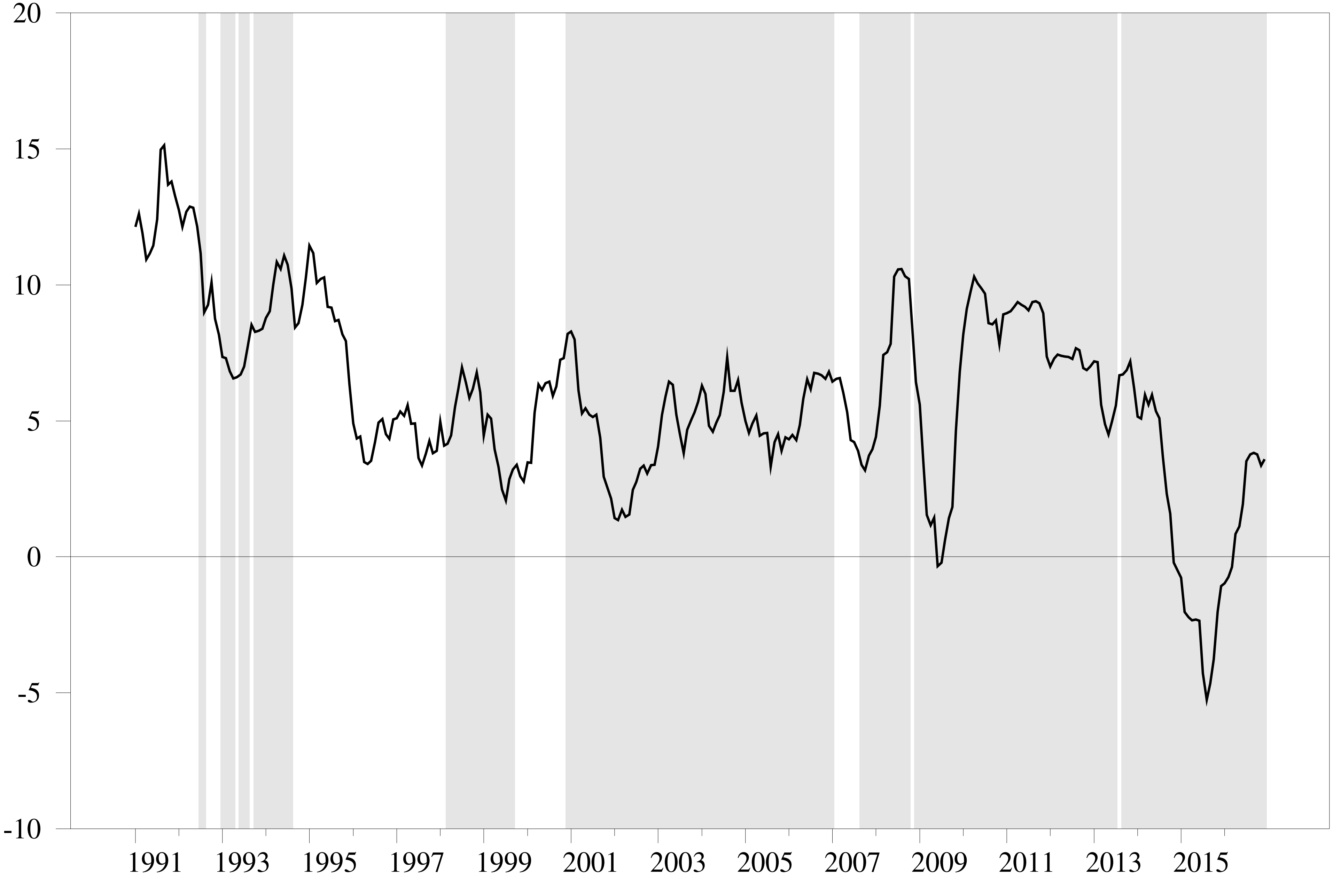


Figure 3.B.2. Inflation and Smoothed Probability of Regime 1

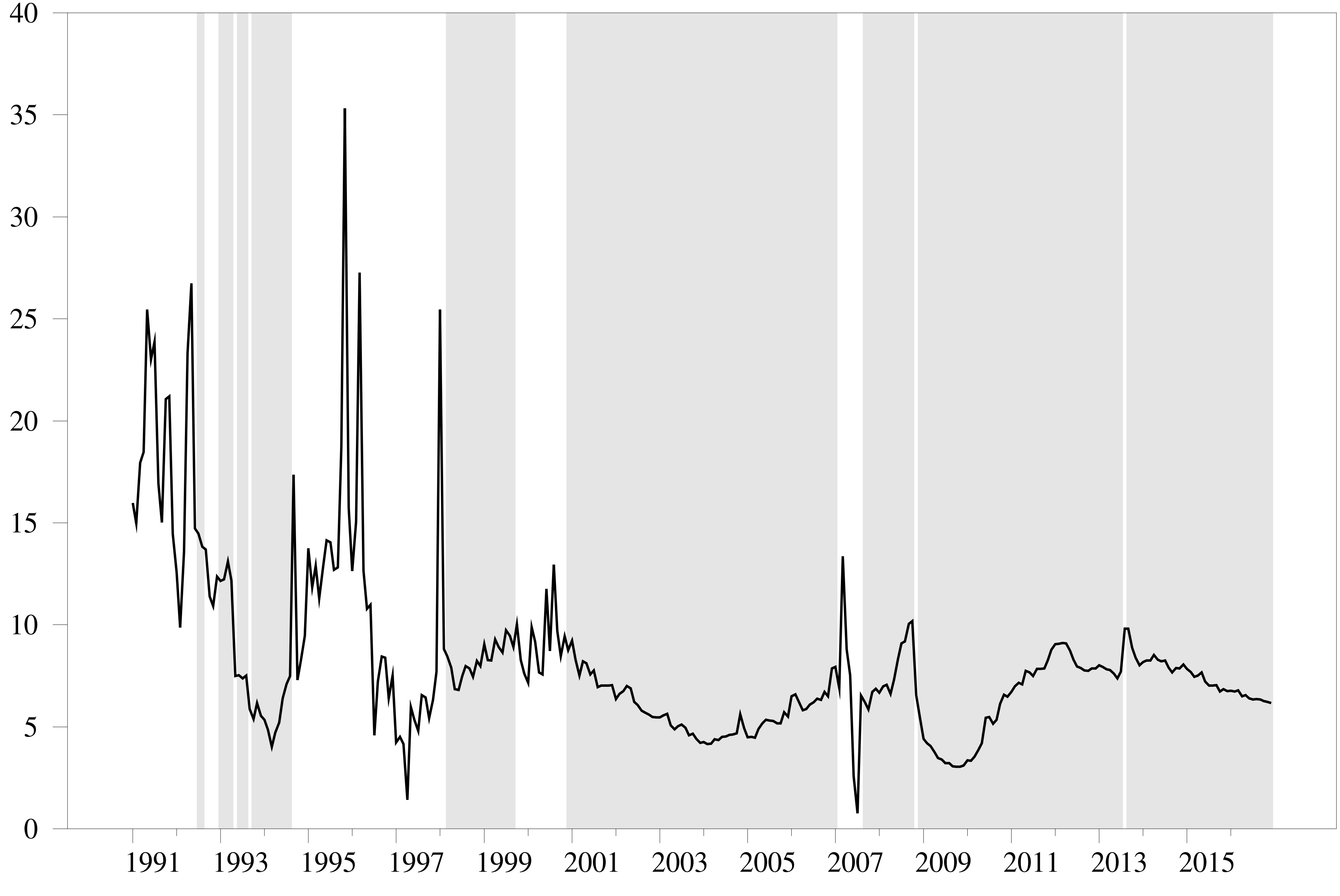


Figure 3.B.3. Interest Rate(WCMR) and Smoothed Probability of Regime 1

4 | Inflation and Openness: An asymmetric analysis

4.1 Introduction

Economic liberalization or in other words increased integration allows economies to take advantage of trade, capital flows, and technology transfers in order to boost their growth. There has been a significant increase in global trade and finance since early 1980s, during the same period majority of developing countries started the process of liberalization. India also started the process of liberalization slowly in mid-1980s and the process picked up rapidly in early 1990s in the backdrop of sever balance of payment crisis of 1990. Massive reforms were carried out in industrial, banking, financial and external sector in India in early 1990s, which resulted in increasing integration of India with the world economy. To look at numbers, India's total merchandise trade as a percentage of the gross domestic product (GDP) increased from 12.72 % in 1990-91 to 43.2 % in 2011-12. Apart from being a period of increased openness, average inflation rate (in terms of GDP deflator) in India came down from 8.2 % in the period 1969-91 to 6.5% in the period 1991-2009. This leads us to the obvious question of whether these two events are related.

Recently some global commentators have claimed that globalization has flattened Phillips curve, meaning that inflation in open economies is less affected by domestic demand conditions and more by the changes abroad. The argument is that foreign supply is more readily substituted for domestic output, hence the pricing power of firms is reduced which operate in more competitive markets and face more elastic demand for their products because of elastic supply from competitors (Borio and Filardo, 2006; I.M.F., 2006; Kohn, 2006; Yellen, 2006). In cotrast to it, others claim that globalization has steepened Phillips curve (Dornbusch and Krugman, 1976; Romer, 1993; Rogoff, 2003). Romer (1993) argues that economies that are more open will have lower inflation because of steeper Phillips curves. The theoretical understanding for why more open economies tend to have less inflation follows from Rogoff's (1985) model, which shows that open economies gain less from surprise inflation and pay the price of monetary expansion more quickly, especially if the exchange rate is floating. The line of argument from both the camps suggests that globalization or openness results in lower inflation. There is ample empirical evidence in support of this negative relationship between trade openness and inflation. Triffin and Grubel (1962) explained this proposition as spillover effect. Whitman (1979) also provides evidence to the spillover effect explanation of the relation. According to new growth theory, openness reduces inflation through its positive influence on output (Jin, 2000), mainly through increased efficiency, better allocation of resources, improved capacity utilization, and increased foreign investment (Ashra, 2002). Alfaro (2005) suggests that real exchange rate depreciation in open economies disincentives monetary expansion.

In the present global scenario, this issue is important because most emerging economies are open, rapid inflation can be serious obstacle in the process of economic development. In this backdrop the empirical question, this chapter seeks to address is whether observed disinflation/inflation is a consequence of increased openness or a statistical fluke in the Indian context. Although India has been included in previous study samples, the openness-inflation relationship has not been extensively examined in Indian context[1]. Despite the fact that multi-country studies capture the long-run relationship between openness and inflation appropriately, however these studies may not identify the nuances of an individual economy properly. Majority of emerging economies may look similar, but they differ from each other at various parameters like socio-economic profile, policy framework, governance set-up etc. Cross-country/panel studies may capture only the average effects of a variable across countries thus ignoring heterogeneity (Nain and Kamaiah, 2014). Further, most of the previous studies have ignored the asymmetric aspect of the relationship between openness and inflation. Given that the evidence on the hypothesized relationship between inflation and openness is partly driven by the country and composition of the sample, the present chapter seeks to test the validity of the hypothesis in the context of India.

The rest of the chapter is organized as follows. The next section provides a brief review of the related empirical literature. The data set and methodology is described in the third section, followed by a section on interpretation of empirical results and the final section concludes.

[1] There are two studies which have been carried out in case of Indian context namely Joshi and Debashis (2010) and Neeraj, Kapoor, and Poddar (2014), but these studies have ignored the presence of asymmetry in the relationship.

4.2 Review of Literature

Before Romer (1993), Triffin and Grubel (1962) found that openness leads to the availability of cheaper goods, and confirmed that more open economies tended to have lower inflation. Iyoha (1973) found a negative relationship between openness and inflation for a sample of 33 countries. Following the classical piece by Kydland and Prescott (1977), which showed that without binding pre-commitment in monetary policy, the rate of inflation is inefficiently high, Romer (1993) found that openness provides this precommitment thus lowering inflation. After Romer's work, other studies found a similar relation between inflation and openness. Lane (1997) found the openness effect to be stronger with the inclusion of country-specific effects, suggesting new channels by which openness could affect inflation, namely, central bank independence and political instability. Terra (1998) studied 114 countries and found a strong inverse relation and argued it was due to the severe indebtedness of Latin American countries during debt crisis period in the 1980s. Ashra (2002), supported the theoretical arguments for the negative relationship between inflation and openness and also pointed out many differences in the magnitude and significance of the variables for the different classifications. Gruben and Mcleod (2004) found an inverse relationship between inflation and trade openness. They found this relationship to be stronger in the countries with floating exchange rate. They also rejected Terra's1998 hypothesis since they found the negative relationship between openness and inflation to be more significant among less indebted economies. Alfaro (2005) found that, in the short run, openness did not play a significant role in controlling inflation, but a regime with fixed exchange rate plays a significant role. Kim and Beladi (2005), found a negative relationship between inflation and trade openness for the developing economies and further demonstrated that central bank dependency did not play an important role in explaining this relationship. Jin (2006) found that a shock to openness has negative effects on growth rate and on the price level but no long-run effects in the South-Korean economy for the period 1960–97. Hanif and Batool (2006), Sachsida, Carneiro, and Loureiro (2003), Bowdler and Malik (2005), Daniels, Nourzad, and VanHoose (2005), Wynne and Kersting (2007), and Badinger (2009), also found a negative relation between trade openness and inflation.

Nasser et al. (2009) showed that the main argument of Romer still holds in the 1990s; however, Terra's criticism fails to hold in the 1990s as the inverse relationship between inflation and openness remains unrestricted to a subset of countries or specific time period. In contrast to the above results, Samimi et al. (2012) found a positive correlation between openness and inflation when traditional trade openness measure was used, and a negative and robust relationship was found between openness and inflation when KOF index as a measure of economic globalization was used.

On the other hand, proponents of cost push hypothesis argue that there is a positive link between trade openness and inflation. Evans (2007) argues that the positive effect of openness on inflation is driven by the fact that the monetary authority enjoys a degree of monopoly power in international markets, as foreign consumers have some degree of inelasticity in their demand for goods produced in the home country. He further argues that open economies possibly can import inflation from the rest of the world via the prices of manufactured imports or raw material. Moreover, as the economy opens up fiscal and monetary policies become less effective. Rajagopal (2007) discussed the impact of trade openness policy on tariff structure, export competitiveness, inflation and economic growth of Latin American countries and approbated a positive relation between openness and inflation. Others like Ghanem (2010), Cooke (2010), Zakaria (2011), and Neeraj, Kapoor, and Poddar (2014) have also found a positive relation between openness and inflation.

Most of the above-reviewed studies are cross-country and may not be able to capture individual country nuances. There are studies which have focused on the dynamics of this relation at the country level, but little has been done in the Indian context. There are only a few studies for India. In a panel study for India, Gupta (2008) argues that financial integration since the mid-1990s has helped India to curb inflation. Joshi and Debashis (2010) investigated the relation between openness and inflation for India using quarterly data from 1984–85 to 2004–05 and concluded that trade openness has significantly contributed to the disinflation process, and the relation has grown strong after the liberalization. However, the measure of openness used as the ratio of imports to GDP, is inadequate. Exports can be promoted even when imports are restricted like Japan and Korea did in the 1960s and 1970s. The promotion of exports deliberately by depreciation or devaluation leads to inflation. The Indian economy was regulated till the 1990s and restrictions were phased out slowly. Hence, in Indian context, the ratio of total trade (imports plus exports) to GDP is a more appropriate measure of openness. Neeraj, Kapoor, and Poddar (2014) used the ratio of total trade to GDP as a measure of openness and found an opposite result. The study used monthly data from April 2004 to December

2013 for India and concluded that openness has contributed to both inflation and its volatility. However, no possible explanation for such results is provided in the study. Moreover, both the studies also have ignored the asymmetry in the relationship.

After analysing the above-reviewed literature, two alternative theoretical views exist concerning the effect of trade openness on Inflation. Openness slows down the rate of inflation according to the spillover hypothesis while according to the cost push hypothesis; openness causes a faster rate of Inflation. Hence, it can be seen that the nature of the relation between inflation and openness is inconclusive Temple (2002), calls it one of the modern puzzles of international economics. Studies using different tests, variables and samples reach different conclusions. One potential reason for contrasting findings is the difficulty in measuring trade liberalization or trade openness. Economic theory does restrict the functional form, but an evolving literature confirms the presence of asymmetric and nonlinear characteristics in macroeconomic variables (Keynes, 2006; Kahneman and Tversky, 1979; Shiller, 1993; Shiller, 2005; Shin, Byungchul, and Greenwood-Nimmo, 2014). To the best of our knowledge, none of the reviewed studies has considered the asymmetry in this relationship. The main motivation of this study is to look into the asymmetric aspects of this relation in the Indian context.

4.3 Data description and methodology

The data used in the empirical analysis is of annual frequency covering the period from 1970–71 to 2013–14 and is collected from the Reserve Bank of India (RBI) database on Indian economy. Specific variables used are Whole Sale Price Index (WPI) which is the price of a representative basket of goods and services, as a proxy for inflation and; Trade (imports plus exports) as a percentage of GDP as a proxy of openness.[2] Exchange rate and GDP per capita are used as a set of additional variables determining steady-state inflation. The choice of sample period period is influenced by the fact that, although, structural and financial reforms commenced in the early 1990s. But trade reforms and other liberalisation measures have been started since mid-1970s (See Mukherji, 2009, and refernces therein). In addition, we chose annual frequency as there is no high frequency data of variables like GDP available prior to 1996. All variables are expressed in logarithmic form. Descriptive statistics for the variables are given in Table 4.1.

The empirical analysis is performed on the following model:

$$Inf = f(To, y, E)$$

where Inf is inflation, To is openness, y is GDP per capita and E is exchange rate

Table 4.1. Descriptive Statistics

Statistics	*LWPI*	*LTO*	*LPCI*	*LEXR*
Mean	3.745	2.779	9.901	3.044
Standard Deviation	0.922	0.527	0.459	0.760
Kurtosis	-1.152	-0.777	-0.874	-1.764
Skewness	-0.228	0.385	0.577	-0.146

Notes: WPI, TO, PCI and EXR denote Inflation, Trade Openness, Per Capita Income and Exchange Rate respectively.

[2]Openness does not have any universally accepted definition. Its different aspects make construction of one index difficult. Common 'single indices' only measure economic dimension of openness like trade openness, the IMF's restrictions measurement, Chinn-Ito index, etc. 'Synthetic indices' measure economic, social, political and environmental dimensions of openness like A.T. Kearney/Foreign Policy Globalization (KFP), KOF, Maastricht Globalization Index, New globalization index etc. There are various shortcomings of each group of indexes but the most robust obstacle is a lack of data (Goldberg and Pavcnik., 2007). In this study, we are looking at the economic dimension of openness thus, we choose trade ratio as a measure of openness. This index for measuring trade openness is the ratio of trade (sum of export and import) to the Gross Domestic Product (GDP) of the country. The trade openness of countries depends on trade policy (restriction on trade) as well as the geographical and economic characteristics of a country.

The standard cointegration approach is used to examine the relationship between inflation and other variables. The linear ARDL (Auto Regressive Distributed Lag Model) (Pesaran, Shin, and Smith, 1999; Pesaran, Shin, and Smith, 2001) is considered good for small samples plus it can be applied even if the regressors have a different order of integration i.e. it is applicable to I(0) and I(1). However, it cannot be applied to I(2). The general form of linear ARDL (p,q) model is:

$$y_t = \alpha_0 + \alpha_1 t + \sum_{i=1}^{p-1} \phi_i y_{t-i} + \beta' x_t + \sum_{i=0}^{q} \beta_i^{*'} \Delta x_{t-i} + \upsilon_t \tag{4.1}$$

$$\Delta x_t = p_1 \Delta x_{t-1} + p_2 \Delta x_{t-2} + ... + p_s \Delta x_{t-s} + \varepsilon_t \tag{4.2}$$

Where x_t is the k-dimensional $I(0)$ or $I(1)$ variables that are not cointegrated among themselves, ν_t and ϵ_t are serially uncorrelated disturbances with zero means and constant variance-covariances, and p_i are $k \times k$ coefficient matrices such that the vector autoregressive process in δx_t is stable. It is also assumed that the roots of $1 - \sum_{i=1}^{p} \phi_i z^i = 0$ all fall outside the unit circle and there exists a stable unique long-run relationship between y_t and x_t.

Assuming linear cointegration among variables is a restrictive assumption. Recent research has suggested that the traditional presumption that the relationship can be well approximated by a simple linear functional form may mislead and that, in fact, a range of nonlinearities may exist (Shin, Byungchul, and Greenwood-Nimmo, 2014, among other). Granger and Yoon (2002) introduced the term 'hidden cointegration', according to whom, two time series have hidden cointegration if their positive and negative components are cointegrated with each other. Hence, standard linear (symmetric) cointegration is a special case of hidden cointegration, and hidden cointegration is a simple case of nonlinear cointegration.

In this analysis, we have applied a recently developed asymmetric ARDL model by Shin, Byungchul, and Greenwood-Nimmo (2014), for detecting nonlinearities focusing on the long-run and short-run asymmetries among economic variables. The asymmetric ARDL model combines a nonlinear long-run relationship with nonlinear error correction by use of carefully constructed partial sum decompositions. Consider the following asymmetric regression:

$$y_t = \beta'^{+} x_t^{+} + \beta'^{-} x_t^{-} + \upsilon_t$$

where x_t is a $k \times 1$ vector of regressors decomposed as:

$$x_t = x_0 + x_t^{+} + x_t^{-}$$

Where x_t^{+} and x_t^{-} are partial sum processes of positive and negative changes in x_t defined by

$$x_t^{+} = \sum_{j=1}^{t} \Delta x_j^{+} = \sum_{j=1}^{t} \max(\Delta x_j, 0), \;\; x_t^{-} = \sum_{j=1}^{t} \Delta x_j^{-} = \sum_{j=1}^{t} \min(\Delta x_j, 0),$$

Where β^{+} and β^{-} are the associated asymmetric long-run parameters. The asymmetric error correction model is:

$$\Delta y_t = \rho y_{t-1} + \theta^{+} x_{t-1}^{+} + \theta^{-} x_{t-1}^{-} + \sum_{j=1}^{p-1} \varphi_j \Delta y_{t-j} + \sum_{j=0}^{q} (\pi_j^{+} \Delta x_{t-j}^{+} + \pi_j^{-} \Delta x_{t-j}^{-}) + \varepsilon_t \quad (4.3)$$

Where $\theta^{+} = -\rho\beta^{+}$ and$\theta^{-} = -\rho\beta^{-}$.

In this framework, the non-standard bounds-based F-test of the null hypothesis

$\rho = \theta^+ = \theta^- = 0$ can be applied to test for the existence of an asymmetric long-run levels relationship (Pesaran, Shin, and Smith, 2001). This approach is valid irrespective of whether the regressors are $I(0)$, $I(1)$ or mutually cointegrated. Similarly, (3) can have the following three special cases: (i) long-run symmetry where $\theta = \theta^+ = \theta^-$ (ii) short-run symmetry in which $\sum_{i=0}^{q} \pi_i^+ = \sum_{i=0}^{q} \pi_i^-$; and (iii.) the combination of long- and short-run symmetry in which case the model collapses to the standard symmetric ARDL model advanced by Pesaran, Shin, and Smith (1999). Both types of restriction can be easily tested using standard Wald tests. Finally, the traverse between short-run disequilibrium and the new long-run steady state of the system can be described as follows by the asymmetric cumulative dynamic multipliers:

$$m_h^+ = \sum_{j=0}^{h} \frac{\partial y_{t+j}}{\partial x_t^+}, \; m_h^- = \sum_{j=0}^{h} \frac{\partial y_{t+j}}{d x_t^-}, \; h = 0, 1, 2 \cdots \tag{4.4}$$

Where m_h^+ and m_h^- tend toward the respective asymmetric long-run coefficients $\beta^+ = \frac{-\theta^+}{\rho}$ and$\beta^- = \frac{-\theta^-}{\rho}$, respectively, as$h \to \infty$. Here x_t is decomposed into x_t^+ and x_t^- about a zero threshold value delineating the positive and negative changes of the growth rate of x_t . This simple approach has an intuitive appeal and provides estimation results that may be easily interpreted.

4.4 Empirical Results

Although, the NARDL approach, can be implemented irrespective of the order of integration of the variables in consideration. Ouattara (2004) pointed out that if the series is integrated of order two i.e $I(2)$, the computed test statistics turns to be invalid. Therefore, to ensure that none of the variables are integrated of order two i.e $I(2)$, we have used Dickey-Fuller Generalized Least Square (DF-GLS) unit root test, which is considered more robust for the small samples than the other standard unit root tests. The results of the 'DF-GLS' are presented in Table 4.1, reveal that all the variables are non-stationary at level but stationary at first difference implying that variables are of integrated of order one.

After ensuring that none of the variable is $I(2)$ or higher, we estimate the nonlinear error correction model of the form (4.3) as below:

$$\Delta lwpi_t = c + \rho lwpi_{t-1} + \theta_1^+ ltgdp_{t-1}^+ + \theta_1^- ltgdp_{t-1}^- + \theta_2^+ lpcr_{t-1}^+ + \theta_2^- lpcr_{t-1}^- + \theta_3^+ lexr_{t-1}^+ + \theta_3^- lexr_{t-1}^- + \sum_{i=1}^{p-1} \varphi_j \Delta lwpi_{t-i} + \sum_{i=0}^{q} \pi_{1,i}^+ \Delta ltgdp_{t-i}^+ + \sum_{i=0}^{q} \pi_{1,i}^- \Delta ltgdp_{t-i}^- + \sum_{i=0}^{q} \pi_{2,i}^+ \Delta lpcr_{t-1}^+ + \sum_{i=0}^{q} \pi_{2,i}^- \Delta lpcr_{t-1}^- + \sum_{i=0}^{q} \pi_{3,i}^+ \Delta lexr_{t-1}^+ + \sum_{i=0}^{q} \pi_{3,i}^- \Delta lexr_{t-1}^- + e_t \quad (4.5)$$

Table 4.1. Augmented Dickey-Fuller unit root tests

At Level	Intercept only		Intercept and trend both	
	Test Statistics	Lags	Test Statistics	Lags
WPI	0.461	1	-1.515	0
TO	1.325	0	-1.609	0
PCI	-0.136	3	-0.701	0
EXR	0.375	1	-1.647	1
At first Difference				
dWPI	-4.631	0	-4.919	0
dTO	-5.148	0	-5.353	0
dPCI	-1.759	2	-7.393	0
dEXR	-4.190	0	-4.328	0
Critical Values				
Level of Significane	1%	-2.621		-3.77
	5%	-1.949		-3.19
	10%	-1.612		-2.89

Notes: The optimal lags of test are chosen based on the Schwartz Information Criteria (SBC).

The cointegration test applied on the above model (Equation 4.5) is an F-test on the joint hypothesis that the coefficients of the lagged level variables are jointly equal to zero. The results show statistically significant evidence for the existence of a long-run cointegrating relationship between the examined variables (Lower Panel of Table 4.2).

The F-statistic (F_{PSS}) for the joint significance of the parameters of the lagged level variables is found 10.615 and exceeds the upper bound critical value. The results of the asymmetric ARDL regression [Eq.4.5] are presented in Table 4.2. The general-to-specific approach is followed for the final NARDL specification. The preferred specification is chosen by starting with $maxp = maxq = 4$ and dropping all insignificant lags. The inclusion of insignificant lags may lead to imprecision in the estimation and may introduce noise into the dynamic multipliers.

After finding the evidences of long-run cointegration among the study variables, next we analyse the long-run and short-run asymmetries. The results of $Wald$-test for long-run (W_{LR}) and short-run (W_{SR}) symmetries are reported in the lower panel of Table 4.3. The result suggests rejection of the null hypothesis of long-run symmetry between the positive and negative components of per capita income (PCI) and exchange rate (EXR) while for trade openness (TO), we cannot reject the null hypothesis. Specifically, W_{LR} for PCI is 493.2 and W_{LR} for EXR is 82.88. Thus, we may reject the null hypothesis of long-run symmetry between the positive and negative components, against the alternative of long-run asymmetry. However, in the case of TO, we cannot reject the null hypothesis as W_{LR} is insignificant.

The results for short-run symmetry in the lower panel of Table 4.3 suggest the rejection of the null hypothesis of short-run symmetry between the positive and negative components of trade openness (TO) and exchange rate (EXR) while for

Table 4.2. Dynamic Asymmetric Estimation

Dependent variable: ΔWPI

Variables	Coef.	t-value	Std. err.	p-value
WPI_{t-1}	-2.147	-6.632	0.324	0.000
TO^{+}_{t-1}	0.053	0.458	0.116	0.657
TO^{-}_{t-1}	-0.365	-2.458	0.148	0.034
PCI^{+}_{t-1}	0.609	2.968	0.205	0.014
PCI^{-}_{t-1}	-6.351	-5.920	1.073	0.000
EXR^{+}_{t-1}	1.383	7.167	0.193	0.000
EXR^{-}_{t-1}	-1.715	-5.591	0.307	0.000
ΔWPI_{t-2}	0.215	2.074	0.103	0.065
ΔWPI_{t-3}	0.124	1.119	0.111	0.289
ΔTO^{+}_{t}	0.115	1.187	0.097	0.263
ΔTO^{+}_{t-2}	0.207	1.982	0.105	0.076
ΔTO^{+}_{t-3}	-0.298	-3.419	0.087	0.007
ΔTO^{-}_{t}	0.386	2.320	0.167	0.043
ΔTO^{-}_{t-1}	0.277	1.813	0.153	0.100
ΔTO^{-}_{t-3}	0.611	4.024	0.152	0.002
ΔPCI^{+}_{t}	0.906	2.545	0.356	0.029
ΔPCI^{+}_{t-2}	0.732	3.810	0.192	0.003
ΔPCI^{+}_{t-3}	0.264	1.331	0.198	0.213
ΔPCI^{-}_{t}	-0.213	-0.762	0.279	0.464
ΔPCI^{-}_{t-1}	2.542	4.603	0.552	0.001
ΔPCI^{-}_{t-2}	0.631	1.503	0.420	0.164
ΔEXR^{+}_{t}	0.667	6.575	0.101	0.000
ΔEXR^{+}_{t-1}	-0.772	-7.396	0.104	0.000
ΔEXR^{+}_{t-2}	-0.549	-5.631	0.097	0.000
ΔEXR^{+}_{t-3}	-0.245	-3.557	0.069	0.005
ΔEXR^{-}_{t}	-0.550	-3.226	0.170	0.009
ΔEXR^{-}_{t-1}	1.164	4.320	0.269	0.002
ΔEXR^{-}_{t-2}	0.266	1.118	0.238	0.290
ΔEXR^{-}_{t-3}	0.841	1.928	0.436	0.083
Constant	4.974	6.736	0.738	0.000
R-squared	0.982	χ^2_{SC}		1.174(0.278)
Adj. R-squared	0.928	χ^2_{HET}		0.030(0.870)
χ^2_{FF}	3.170(0.094)	χ^2_{NOR}		8.770(0.012)
t_{BDM}	-6.318	F_{PSS}		10.615

Notes: The superscripts '+' and '−' denote positive and negative partial sums respectively. χ^2_{SC}, χ^2_{NOR}, χ^2_{HET} and χ^2_{FF} Denote LM tests for serial correlation, normality, heteroscedasticity and functional form. General to specific approach followed to choose the final NARDL specification.

Table 4.3. Short-run and Long-run Symmetry test

Exog. var.	Long-run effect [+]			Long-run effect [-]		
	Coef.	F-stat	$P-Value$	Coef.	F-stat	$P-Value$
TO	0.025	0.214	0.653	0.170	5.442	0.042
PCI	0.284	15.550	0.003	2.957	908.700	0.000
EXR	0.644	772.100	0.000	0.799	34.320	0.000
	$Long-run(W_{LR})$			$Short-run(W_{SR})$		
		Statistics	$P-Value$		Statistics	$P-Value$
TO		3.002	0.114		11.930	0.006
PCI		493.200	0.000		1.129	0.313
EXR		82.880	0.000		6.951	0.025

Notes: The upper panel of the table shows the long-run asymmetric effect on the dependent variable. In the lower panel, W_{LR} denotes the Wald test for long-run symmetry testing and W_{SR} denotes the Wald test for short-run symmetry testing.

per-capita income null cannot be rejected. Specifically, W_{SR} for TO is 11.93 and W_{SR} for EXR is 6.951. However, W_{SR} for PCI being insignificant, we cannot reject the null hypothesis. These results support that model specification is important in analysing this relation because a linear model for inflation and other macroeconomic variables in this study would have been inappropriate. Thus, results show that effect of trade openness (TO) and exchange rate (EXR) in the short run is asymmetric, whereas per capita income (PCI) is symmetric.

The results of long-run dynamics are reported in the upper panel of Table 4.3. Specifically, the estimated long-run positive coefficient of TO is insignificant while the estimated long-run negative coefficient of TO is significant. The estimated long-run coefficient of TO^+ is 0.025 and TO^- is 0.17. The estimated long-run coefficient of TO^+ is statistically insignificant and very small 0.025 hence, raising doubt regarding its accuracy. But the long-run coefficient of TO^- is significant so we may conclude analytically that a 1% decrease in trade openness leads to 0.17% decrease in inflation. A possible explanation for the long-run coefficients of trade openness being insignificant or small in size may be due to the fact that TO is only a measure of ex-post openness; it may not be a good measure of the ex-ante openness of the economy. But the positive linkage between inflation and openness as found in this study is in line with the general notion of outward-orientation being inflationary for developing economies (see among others Evans, 2007; Jalil, Tariq, and Bibi, 2014). This positive link in Indian context seems to be logical due to the importance of imports, particularly oil and other manufactured goods in total trade, which has an intensifying effect on the inflationary process of the economy because of increasing world oil prices and manufacture goods.[3] Regarding PCI and EXR both positive (PCI^+ and EXR^+) and negative (PCI^- and EXR^-) long-run coefficients are significant and the signs being positive in line with theory. The estimated long-run coefficient of PCI^+ is 0.284 and PCI^- is 2.95. Therefore, we may conclude that a 1% increase in income leads to 0.284% increase in inflation and a 1% decrease in income leads to 2.95% decrease in inflation. The positive linkage between real income and inflation is possible because a rapid rate of growth of income may cause inflation because of the appearance of bottlenecks or a general difficulty to shift resources around at short notice (Conlisk, 1970). The positive relation between income and inflation can be interpreted as a structuralist view of the inevitable occurrence of inflation during the process of development (Iyoha, 1973).

Moving to the exchange rate, the estimated long-run coefficient of EXR^+ is 0.644 and EXR^- is 0.799.So we can conclude that a 1% increase in the exchange

[3]However, at times global oil price have decreased, but the pass-through has been either absent or very limited. Moreover, studies on the effect of oil price on domestic inflation also suggest that the nature of effect is asymmetric (See Hamilton and Herrera, 2001; Davis and Hamilton, 2003, among others).

rate(depreciation) leads to 0.644% increase in inflation, and a 1% decrease in the exchange rate (appreciation) leads to 0.799% decrease in inflation. This positive link between exchange rate and inflation supports conventional purchasing power parity theory.

The results of the study clearly show that presuming a symmetric relationship between trade openness and inflation may mislead to get wrong inferences as in the previous studies. It is evident that both negative and positive change in openness, over short-run and long-run have a differential impact. The results of asymmetry also highlight the presence of price stickiness in Indian economy (See among others Tripathi and Goyal, 2013). Moreover, results also proved that control variables also have a differential impact. At the policy level, policy framework should be more dynamic and adaptive to changing scenario of global as well as the domestic economy.

The analysis of dynamic effects of the explanatory variables on inflation can be further explained by dynamic multipliers. Figure 1 plots the dynamic effects of positive and negative changes in trade openness, per capita income and exchange rate on the inflation. We may observe that the gap between the effect of positive and negative changes in the trade openness at the beginning of the period is small and over the horizon it widens further. At the end of the five-time horizon, the effect of positive change is much greater than negative change. Overall, it may be observed that the dynamic adjustment of the effects due to positive and negative changes on the inflation is quite opposite to each other. A similar trend is observed in the case of per capita income though there is a more sharp reaction to negative change compared to positive change. In a reverse of the two in the case of the exchange

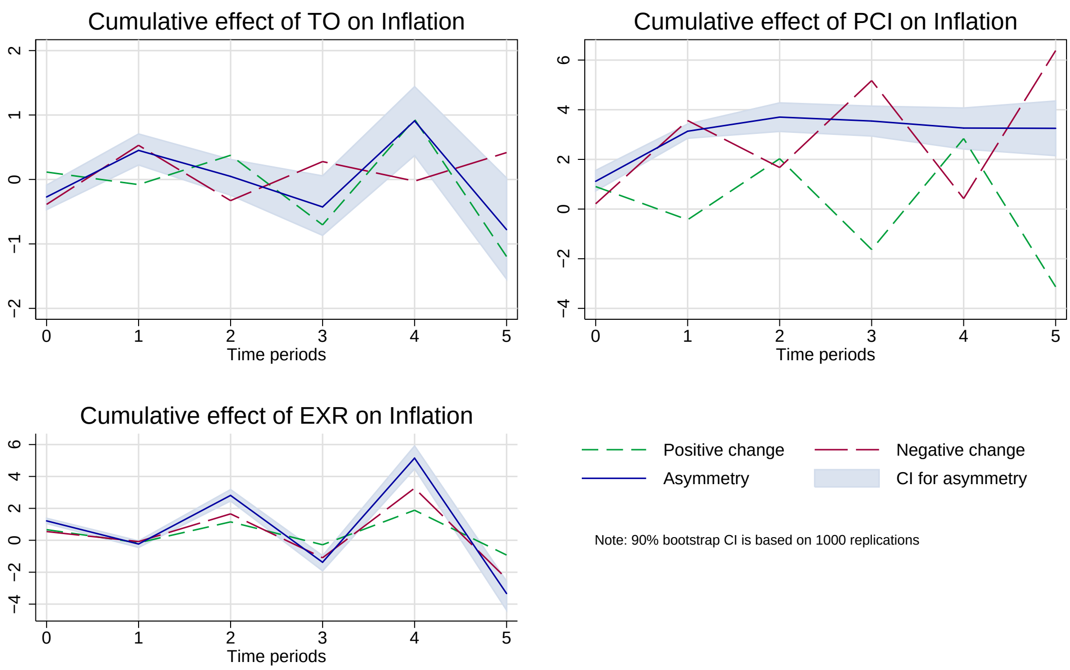


Figure 4.1. Dynamic Multipliers

rate, till the four-time horizon period, the effects of positive and negative change in the exchange rate has an almost similar effect, though as the horizon expands, they diverge from each other.

Overall, it may be concluded that the dynamic effects of trade openness, exchange rate and per capita income further support the asymmetric result found in the analysis. The positive and negative changes in trade openness, exchange rate and per capita income do not have a same and equal effect on inflation in the Indian context.

4.5 Conclusion

The Indian economy is rapidly integrating with the global economy. The domestic price level cannot remain immune to external shocks. This paper empirically analyses the relationship between inflation and trade openness in India using annual time series data for the period 1970 to 2014 from RBI. The variables analysed are WPI as a proxy for inflation, trade (imports plus exports) percentage of GDP as a proxy for openness. Besides additional macroeconomic variables like per-capita income and exchange rate were also examined. We used asymmetric cointegration approach (non-linear ARDL) which enables investigation of possible asymmetric effects in both the long- and short-run. In other words, it helps to examine the effects of positive and negative changes of the explanatory variables on dependent variable. The results show a positive relation between inflation and trade openness thus refuting Romer (1993) and others who argue that openness serves as a mechanism to restrain inflation. Moreover, the relation among inflation, exchange rate and per capita income are also positive and significant.

Our study found long-run asymmetric effects from per-capita income and exchange rate towards inflation, and no long-run asymmetric effect from trade openness to inflation. This showed that presuming a symmetric relationship like in previous studies (Joshi and Debashis, 2010; Neeraj, Kapoor, and Poddar, 2014 among others) may be misleading. Regarding the short-run, significant asymmetric effects from trade openness and exchange rate are found towards inflation, but no significant short-run asymmetric effect from per capita income to inflation. The overall response of inflation towards positive and negative changes in trade openness, exchange rate and per capita income differed significantly. The results also reveal that there is presence of price rigidity in Indian market as argued by Tripathi and Goyal (2013).

The positive relationship between inflation and trade openness has important policy implications in the Indian context, particularly for optimal trade policy. India is an importing economy in which more openness may make it vulnerable to the external shocks. It follows, therefore, that the optimal policy stance will be contingent on the stage of the development. The other macro variables used in this study namely per-capita income and exchange rate have expected and significant impact on the domestic inflationary process. This shows the importance of monetary as well as other domestic policies as determinants of inflationary process in India.

* * * * *

5 | Summary of Findings

In this study, we explore different roles of uncertainty (nominal and real) on macroeconomic performance and also on the of monetary policy effectiveness. Further, we examine the effect of openness on inflation. The thesis has three core empirical chapters in addition to an introductory chapter. Each of these chapters is self content and has its own structure. The study period and methodology varies from chapter to chapter. We have used different methodologies according to the need and appropriateness of each chapters.

The first chapter gives introduction and study background and outlines plan of the study. In the second chapter, we explore the relationship between nominal (inflation) and real (output growth) uncertainty, inflation and output growth. We have used data of monthly frequency for the period of April 1971 to December 2016. The variables used are annualised growth rate of IIP and WPI in percentage terms, respectively as proxy for output growth and inflation. We employed asymmetric VARMA-GARCH-in-Mean model following Grier et al. (2004). This method allows us to incorporate the asymmetric and spill over effects, the issue raised by Brunner and Hess (1993). Further, we used simultaneous approach on account of Pagan's (1984) criticism of two-step procedure.

Prior to examining the relationships among the variables, we have used various specification and diagnostic tests to check the appropriateness and fit of the model. The results of the specification and diagnostic tests show that the employed model is appropriate and properly specified. Results reveal that both nominal and real uncertainty affects inflation and output growth. We find evidence for the Cukierman-Meltzer hypothesis. The results also support Friedman (1977) and Pindyck's (1991) hypothesis. That is, a rising inflation uncertainty inhibits growth. In case of real uncertainty, we find evidences for significant relationships between real uncertainty, output growth and inflation. We find that real uncertainty negatively affects output growth, but has positive effect on inflation. Further, we find that negative and positive shocks of equal magnitude do not have equal effect. Our results clearly points that both nominal and real uncertainty have adverse effect on output growth. The results show the importance of low and stable and predictable inflation, for a stable output growth. These may be achieved by implementing polices like quick response to shocks, more transparent policies and wide information dissemination and creating credibility of central institutions especially monetary authorities among other policies.

In the third chapter, we empirically examine the recently emerged debate regarding the role of uncertainty in monetary policy transmission. After the global financial crisis (GFC), there is a continuously evolving body of theoretical and empirical literature which suggests that uncertainty lessens the effectiveness of monetary policy. We empirically examine the influence of uncertainty on the monetary policy effectiveness in India. To this end, we use monthly data for the period, April 1991 to December 2016. The variables used in the study are output growth, inflation and weighted average call money rate. We use annualised growth rate of index of industrial production (IIP) for output growth and wholesale price index (WPI) for inflation. We use weighted average call money rate for the monetary policy stance. We employ Bayesian Markov Switching VAR, a non-linear VAR, which allows us to examine the effect of monetary policy shocks during high and low uncertainty periods.

The results show that uncertainty influences effectiveness of monetary policy shocks. The effects of the monetary policy shocks are weaker during high uncertainty regime relative to low uncertainty regime. More specifically, we find that an increase in interest rate (tight monetary policy) leads to a fall of output growth in high uncertainty regime by about half of the fall in output growth, when uncertainty is low. A similar pattern of effects of tight monetary policy is observed for inflation also. The results are in favour of the theoretical propositions that uncertainty reduces the effectiveness of monetary policy. Findings of the study suggest to have a state-dependent and more aggressive policy response when economy is in high uncertainty regime.

In the fourth chapter, we examine the relationship between inflation and openness in India over the period of 1970 to 2014. We use WPI as a measure for inflation and trade (imports plus exports) percentage of GDP, a measure for openness. We also include macroeconomic variables namely per-capita income and exchange rate as control variables in the model. All the variables are of annual frequency. We employed asymmetric cointegration approach (non-linear ARDL) which allows us to examine the possible asymmetric effects of negative and positive changes in the explanatory variables on the dependent variables, both in long and short run.

The results show a a significant and positive relation between inflation and openness thus rejecting Romer (1993) and others arguments that openness serves as a mechanism to restrain inflation. In the long-run, there are asymmetric effects of per-capita income and exchange rate on inflation, but, openness has symmetric effect on inflation. While in short-run, openness and exchange rate are found to have asymmetric effects on inflation, there is no significant short-run asymmetric effect from per capita income to inflation. The overall response of inflation towards positive and negative changes in trade openness, exchange rate and per capita income differed significantly. This shows that presuming a symmetric relationship like in previous studies (Joshi and Debashis, 2010; Neeraj, Kapoor, and Poddar, 2014 among others) may be misleading. These results also reveal that there is presence of price rigidity in Indian market as argued by Tripathi and Goyal (2013). The results suggest that India being an importing economy, more openness may make it vulnerable to external shocks. It follows, therefore, that the optimal policy stance will be contingent on the stage of the development.

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