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The Relationship between Inflation, Inflation Uncertainty and Output Growth in India

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The Relationship between Inflation, Inflation Uncertainty and Output Growth in India

Bipradas Rit*

Abstract

Friedman's hypothesis regarding the relationship between inflation, inflation uncertainty and output growth states that full employment policy objective of the government tends to increase the rate of inflation which increases the uncertainty about the future course of inflation. Increase in inflation uncertainty lowers economic efficiency and reduces output growth. Most of the studies to test the Friedman hypothesis are made for the developed countries. There are very few studies for underdeveloped countries particularly for India regarding the relationship between inflation, inflation uncertainty and output growth. Thornton's (2006) study regarding the relationship between inflation and inflation uncertainty in India is univariate in nature and it cannot establish the relationship between inflation uncertainty and output growth. This study intends to use the bivariate GARCH model to find out the relation between inflation, inflation uncertainty and output growth simultaneously. In this study we use monthly data of wholesale price index (WPI) and index of industrial production (IIP) of India as the proxies of price and output respectively from 1950:1 to 2009:8. Following Fountas, Karanasos and Kim (2002) we have used the following bivariate GARCH model to estimate simultaneously the means, variances and covariances of inflation and output growth. We use Granger- causality test to know the statistical relationship between average inflation, output growth, inflation uncertainty and output growth uncertainty. We find strong evidence that increase in average inflation raises inflation uncertainty and increase in growth rate increases the growth rate uncertainty. But we do not find any statistically significant relationship between inflation uncertainty and output growth rate. This analysis suggests that price stability must not be the main focus of policy prescription.

JEL Classification: E31.

Keywords: Inflation, Output, Volatility, ARCH.

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The Relationship between Inflation, Inflation Uncertainty and Output Growth in India

1. Introduction

Since the publication of Noble Lecture of Milton Friedman (1977), the relationship between inflation, inflation uncertainty and output growth has been an important subject of large number of empirical investigations. Friedman's hypothesis regarding the relationship between inflation, inflation uncertainty and output growth consists of two arguments. The first states that full employment policy objective of the government tend to increase the rate of inflation which creates a strong pressure to counter it. The perception of this pressure increases the uncertainty about the future course of inflation. The second argument is that increase in inflation uncertainty lowers economic efficiency and reduces output growth.

Cukierman and Meltzer (1986) used the Barro-Gordon model in which the Federal Reserve Bank dislikes inflation but tries to stimulate the economy by surprise inflation. In Cukierman and Meltzer model both the policy maker's objective function and money supply are random variables. When there is higher inflation public fail to infer whether higher inflation is due to random increase in money supply or it is due to the increased weight being given on employment generation by Federal Bank. The increased uncertainty raises the average inflation rate because it provides an incentive to the policy maker to create an inflation surprise in order to stimulate economic growth. In Cukierman and Meltzer model inflation uncertainty causes higher inflation whereas Friedman argued that high inflation creates inflation uncertainty.

In contrast with the Cukierman and Meltzer model Holland (1995) adopted the "stabilising hypothesis" regarding the behavior of the central bank. According to Holland, if there is an increase in inflation uncertainty due to increasing inflation the monetary authority will contract money supply to eliminate inflation uncertainty. Thus according to Holland inflation uncertainty reduces inflation.

Deveraux (1989) said that increase in output growth uncertainty raises average rate of inflation. He used the Barro-Gordon model to show that more output growth uncertainty will reduce the optimum amount of wage indexation. This will encourage the policy makers to create inflation shocks to increase the output growth rates.

Black (1987) predicted that more output growth uncertainty should lead to higher output growth. To him investment in more risky technology (increase in output growth uncertainty) would result in more output growth.

In the literature of inflation uncertainty two methods were generally used; (i) the cross section dispersion of individual forecasts from surveys and (ii) moving standard deviation of variable under consideration. Survey based measures summarise the range of disagreement among individual forecasters at a point of time but they do not give information about each individual's uncertainty regarding their own forecast. Each forecaster may be extremely uncertain about future events but they may submit very similar estimate at a point of time. In that case the survey measure would fail to capture the amount of existing uncertainty [Zarnowitz and Lambros (1987)]. Moving standard deviation shows the predictable fluctuation of a variable which is different from uncertainty. Studies made by Mullineaux (1980), Gale (1981), Fischer (1981), Kastimbris and Miller (1982, 1984), Kastimbris (1985) used either of the two methods stated above. In a major departure from the above two methods the modern studies use conditional variance as the measure of uncertainty. The new method follows from the pioneering work of Engle (1982) on the autoregressive conditional heteroskedasticity (ARCH) approach.

Grier and Perry (2000) used the GARCH-M model to measure uncertainty and simultaneously test the possible effects of uncertainty on inflation and output growth in a single equation model. They pointed out that GARCH estimates a time-varying residual variance that corresponds well to the notion of uncertainty. GARCH estimation gives an explicit test of whether the movement in the conditional variance of a variable over time is statistically significant. It allows simultaneous estimation of conditional variance equations and the mean equations for the variables under considerations. They could not find any effect of inflation uncertainty and output growth uncertainty on average inflation for US economy for the period of 1948 to 1996. They have shown that inflation uncertainty significantly lowers the output growth rate which supports Friedman's argument.

Fountas (2001) used the annual data on consumer price index of UK for the period 1885-1998 to test the relationship between inflation and inflation uncertainty in the UK. He used the GARCH(1,1) model where inflation series follows AR(1) process. Dummy variables were used to capture high inflaton periods in the sample. The results provided strong evidence that inflationary periods were associated with high inflation uncertainty.

Hwang (2001) used the monthly data of inflation of US to examine the relationship between inflation and inflation uncertainty. The study could not provide any evidence such that high inflation rate would lead to high inflation uncertainty.

Fountas, Karanasos and Kim (2002) used bivariate GARCH model of inflation and output growth to simultaneously estimate the conditional means, variances and covariances of inflation and output growth. They applied the Granger causality test to examine the causal relationships between (i) infaliton and output growth and (ii) uncertainty about inflation and output growth. Using the monthly data of producer price index (proxy of price level) and industrial production index (proxy of output) for the period of 1961 to 1999 they found that higher inflation and higher inflation uncertainty led to lower output growth of the Japanese economy.

Apergis (2004) investigated whether there is any presence of causality among inflation, output growth and inflation volatility in G7 countries. Apergis estimated GARCH(1,1) model and the panel causality tests revealed that inflation causes inflation uncertainty. The results also that inflation affects output growth.

Thronton (2006) used the GARCH(1,1) model to examine the relationship between inflation and inflation uncertainty in India for the period of 1957 to 2005. A positive and significant relationship between inflation and inflation variability was found. The Granger causation showed inflation caused inflation uncertainty as hypothesized by Friedman. But the relationship between inflation uncertainty and output growth was not examined.

Using a bivariate EGARCH-M model Wilson (2006) investigated the relationship between inflation, inflation uncertainty and output growth for Japan. The EGARCH-M model permits the measure of inflation uncertainty to respond to the direction of change in inflation. Wilson found that increased inflation uncertainty raises average inflation and lowers average growth and increased growth uncertainty raises average inflation.

From the brief survey of literature on the relationship between inflation, inflation uncertainty and output growth we see that the methodologies applied by relatively modern studies in the form of GARCH model are far more superior than the previously used survey based method and moving standard deviation. Again the studies using the GARCH models both the univariate and bivariate models are used. But bivariate model is superior since the model allows us to simultaneously estimate equations for the means of inflation and output growth that include conditional variance of both series as regressors, along with the time-varying residual covariance matrix. (Grier and Perry).

Most of the studies to test the Friedman hypothesis are made for the developed countries. There are very few studies for underdeveloped countries particularly for India regarding the relationship between inflation, inflation uncertainty and output growth. In the post independence period India experienced a moderate rate of inflation compared to the hyperinflationary developing economies. In India a large share of the total population are living below and around the subsistence level of income and a relatively small increase in inflation rate adversely affect their living standard. Thus there is much concern among the economists regarding the inflation rate in India. The earlier studies like Bhattacharya and Lodh (1990), Das (1992), Thacker (1992) all concerned with the determinants of inflation in India. Thornton’s (2006) study regarding the relationship between inflation and inflation uncertainty in India is univariate in nature and it cannot establish the relationship between inflation uncertainty and output growth. Thornton found that higher inflation caused more inflation uncertainty in India. Therefore, in his opinion higher inflation had “possible” negative output effect. In this study we use the bivariate GARCH model to investigate the relation between inflation, inflation uncertainty and output growth simultaneously.

2. Data

In this study we use monthly data of wholesale price index (WPI) and index of industrial production (IIP) of India as the proxies of price and output respectively from 1950:1 to 2009:8. Data are obtained from the International Financial Statistics of the International Monetary Fund. Inflation (π) is measured by the monthly difference of log WPI:

$$\pi_t = log\left(\frac{WPI_t}{WPI_{t-1}}\right) \qquad (1)$$

Real output growth is measured by the monthly difference in the log of IIP:

$$y_t = log\left(\frac{IIP_t}{IIP_{t-1}}\right) \qquad (2)$$

We start with the unit root test of the logarithmic transformation of WPI and IIP series to test the stationarity of the data. We have applied both the Augmented Dicky-Fuller test and Phillips-Perron test to determine the stationarity of a variable. The results of Augmented Dicky-Fuller test and Phillips-Perron test applied on the price and output series are shown in Table 1 and Table 2 respectively. Both the tests are conducted in level and in first difference. The optimum lag length in case of Augmented Dicky-Fuller test is selected on the basis of the Akaike Information Criteria. For the Phillips-Perron test truncation lag is selected on the basis of recommendation of Newey – West.

Table 1: Results of Unit Root Test (Augmented Dicky-Fuller Test) on WPI and IIP

Test series	ADF test statistic(in level)	P Value	ADF test statistic(in first difference)	P Value
WPI	0.715	0.993	-13.688	0.000
IIP	0.015	0.959	-6.295	0.000

Notes: The number of observations (n) is 716. Lag lengths are selected on the basis of minimum AIC. For WPI in level lag length is 4 for IIP it is 17. For 1st difference in WPI the lag is 3. For IIP in first difference lag length is 16. The critical values: at 1% is –3.439, at 5% is -2.865 and at 10% is -2.569.

Table 2: Results of Unit Root Test (Phillips-Perron Test) on WPI and IIP

Test series	PP test statistic (in level)	P Value	PP test statistic (in first difference)	P Value
WPI	0.714	0.992	-24.199	0.000
IIP	-0.297	0.923	-130.723	0.000

Notes: The number of observations (n) is 716. For WPI in level lag length is 4. For 1st difference in WPI the lag is 3. For IIP lag lengths are 17 and 16 for data in level and first difference respectively. The critical values: at 1% is –3.439, at 5% is -2.865 and at 10% is -2.569.

From the above two tables we can see that the null hypothesis of unit root cannot be rejected for price and output series. But the null hypothesis of non stationary can be rejected for the data series in first difference. Thus the price and output series are integrated of order one. Given the two series are integrated of same order we can proceed for the test of co-integration. We first use the Engle-Granger method. We estimate the following equations

$$IIP_t = \beta_0 + \beta_1 WPI_t + e_{1t} \tag{3}$$

$$WPI_t = \gamma_0 + \gamma_1 IIP_t + e_{2t} \tag{4}$$

If the residual series does not contain unit root then we can say that the two series are co-integrated. We consider the following autoregression of the two series of residuals

$$\Delta\hat{e}_t = a_1\hat{e}_{t-1} + \sum_{i=1}^{n} a_{i+1}\Delta\hat{e}_{t-1} + \epsilon_t \tag{5}$$

The regressions of residuals of equation (3) and (4) are estimated for maximum lag length of 25. The appropriate lag lengths of Augmented Dicky Fuller test on the residuals are selected on the basis of Akaike Information Criteria. Equation (5) is estimated for 17 lags for residuals of equation (3). The estimated test statistic is -3.527 (with p value 0.000) is less than the critical value at 1% level (-2.568). Again for residuals of equation (4) ADF test is conducted for 24 lags. The estimated test statistic is -2.662 (with p value 0.009) is less than the critical value at 1% level (-2.568). Thus both the residual series do not contain any unit root and we can say that the price and output series are co-integrated.

Table 3: Test for Serial Correlation and ARCH

Tested Series	Q(4)	Q(8)	LM(4)
π	0.636 [1.000]	2.156 [0.976]	57.531 [0.000]
y	0.823 [0.999]	1.092 [0.998]	11.492 [0.000]

Numbers in [] are p values

Next we proceed for serial correlation and autoregressive conditional heteroskedasticity (ARCH) test in inflation (п) and output growth (y) series. We have estimated the residuals of the AR (4) process of п and AR (16) for y series according to the Akaike Information Criterion. We have performed the Ljung-Box test for serial correlation and Lagrange Multiplier test for ARCH. The results are shown in Table 3. The Q statistics for the π series at 4 and 8 lag are 0.0636 and 2.1564 respectively with p values 1.000 and 0.976. Thus the null hypothesis that there is no autocorrelation up to order 4 and 8 is not rejected. Similar results are seen for the y series also. The Lagrange Multiplier (LM) test statistic with 4 lags on the square of residuals of the π series is 57.5310 with p value 0.000. Thus the null hypothesis that there is no ARCH effect in π series is rejected. Similar result is seen for the residuals of the y series. Thus we can say that the data on inflation and output growth are conditionally heteroskedastic but not serially dependent.

3. Empirical Methodology

The first ARCH model was presented by Engle (1982). The model says that the variance of the residuals at time t depends on the squared error terms of the past periods. According to Engle a major limitation of the ARCH model is that it looks like a moving average specification than an autoregression. A new idea was evolved which was to include the lagged conditional variance terms as autoregressive terms. Bollerslev (1986) worked out the idea in his paper entitled "Generalized Autoregressive Conditional Heteroskedasticity". To illustrate the GARCH (p,q) model we may start with an m th order autoregressive process of the conditional mean of inflation:

$$\pi_t = a + \sum_{i=1}^{m} \beta_i \pi_{t-i} + \epsilon_t \qquad (6)$$

where ϵ_t is the shock to inflation at time t. Here ϵ_t is assumed to be normally distributed with a zero mean and time varying conditional variance ht which is specified as the linear function of past squared inflationary shocks and past variances. Therefore

$$h_t = \gamma_0 + \sum_{i=1}^{p} \delta_i h_{t-i} + \sum_{j=1}^{q} \gamma_j \epsilon_{t-j}^2 \qquad (7)$$

Now given that the inflation series possess the heteroskedastic errors this conditional variance constitute a direct time varying measure of inflation uncertainty. When we have two series of expected inflation and output growth the sequence of estimated conditional variances can be used to perform separate time series analyses of the relationship between inflation uncertainty and inflation and output growth and inflation uncertainty. [Wilson (2006)]

Following Fountas, Karanasos and Kim (2002) we have used the following bivariate GARCH model to estimate simultaneously the means, variances and covariances of inflation and output growth:

$$\pi_t = \gamma_{\pi 0} + \sum_{i=1}^{24} \delta_{\pi\pi,i}\pi_{t-i} + \sum_{i=1}^{24} \gamma_{\pi y,i}y_{t-i} + \epsilon_{\pi t} \tag{8}$$

$$y_t = \gamma_{y0} + \sum_{i=1}^{24} \delta_{y\pi,i}\pi_{t-i} + \sum_{i=1}^{24} \gamma_{yy,i}y_{t-i} + \epsilon_{yt} \tag{9}$$

In this VAR (24) model πt and yt denote the inflation and output growth. We define the residual vector ϵ t as $\epsilon_t = (\epsilon_{\pi t}, \epsilon_{yt})'$, where $\epsilon_{\pi t}, \epsilon_{yt}$ are the shocks to inflation and output growth respectively at t. The standardized value of the residuals $(\nu_{i,t-j} = \epsilon_{i,t-j}/\sqrt{h_{i,t-j}})$ is i.i.d. with zero mean and unit variance for $i = \pi, y$. We assume the constant correlation GARCH (1,1) structure on the conditional covariance matrix Ht:

$$h_{\pi t} = \alpha_\pi + \theta_\pi h_{\pi,t-1} + \omega_\pi \epsilon^2_{\pi,t-1} \tag{10}$$

$$h_{yt} = \alpha_y + \theta_y h_{y,t-1} + \omega_y \epsilon^2_{y,t-1} \tag{11}$$

$$h_{\pi y,t} = \rho\sqrt{h_{\pi t}}\sqrt{h_{yt}} \tag{12}$$

where $h_{\pi t}$, h_{yt} denote the conditional variances of the inflation rate and output growth respectively. $h_{\pi y,t}$ is the conditional covariance between $\epsilon_{\pi t}$ and ϵ_{yt}. It is assumed that $\alpha_i > 0$, $\omega_i > 0$, $\theta_i \geq 0$ $(i = \pi, y)$ and $-1 \leq \rho \leq 1$.

Bollerslev (1990) stated that the constant correlation model is computationally attractive. He said that the correlation matrix can be concentrated out from the log likelihood function, resulting in a reduction of parameters to be optimized. Again it is relatively easy to control the parameters of conditional variance equations during the optimization so that h_{it} is always positive.

Equations (7) to (11) are estimated using the numerical optimization algorithm BHHH suggested by Berndt, Hall, Hall and Hausman (1974) to obtain the maximum likelihood estimates of the parameters. Generally $(\epsilon_{\pi t}, \epsilon_{yt})$ is assumed to be distributed bivariately normal or student t. The normality assumption is adopted in this study.

Results

To determine the lag structure of equations (8) and (9) we have used the Akaike Information Criterion. We have considered the maximum lag length of 30 to determine the optimum lag length. The lag length 24 is selected on the basis of AIC. The results are shown in Table 4

Table 4: Estimation of Bivariate GARCH Model

Bivariate AR (24) – constant conditional correlation GARCH (1, 1) model

$$\pi_t = \underset{(3.61)}{0.0024} + \underset{(3.81)}{0.2249}\,\pi_{t-1} + \underset{(3.20)}{0.1814}\,\pi_{t-3} - \underset{(-3.25)}{0.1772}\pi_{t-4} - \underset{(1.99)}{0.0967}\pi_{t-8} + \underset{(5.41)}{0.2310}\,\pi_{t-11} - \underset{(-2.28)}{0.0949}\pi_{t-14} - \underset{(-2.48)}{0.0559}\,y_{t-3} - \underset{(-2.83)}{0.0022}\,y_{t-4} \quad (13)$$

$$y_t = \underset{(4.05)}{0.0063} - \underset{(2.62)}{0.1960}\,\pi_{t-19} + \underset{(4.05)}{0.4027}\,\pi_{t-20} - \underset{(-2.15)}{0.1820}\pi_{t-21} - \underset{(-11.22)}{0.5266}y_{t-1} - \underset{(-5.90)}{0.3364}\,y_{t-2} - \underset{(-4.08)}{0.2340}y_{t-3} - \underset{(-4.43)}{0.2380}\,y_{t-4} - \underset{(-3.00)}{0.1730}\,y_{t-5} - \underset{(-2.38)}{0.1408}\,y_{t-6} - \underset{(-2.57)}{0.1391}\,y_{t-8} + \underset{(8.15)}{0.4366}\,y_{t-12} + \underset{(2.84)}{0.1658}y_{t-13} + \underset{(1.99)}{0.1151}\,y_{t-14} - \underset{(-2.66)}{0.1330}\,y_{t-21} - \underset{(-2.80)}{0.1286}\,y_{t-23} + \underset{(3.84)}{0.1634}\,y_{t-24} \quad (14)$$

Conditional variance/ covariance equations

$$h_{\pi t} = \underset{(1.92)}{0.000000708} + \underset{(7.41)}{0.2546}\epsilon^2_{\pi,t-1} + \underset{(30.25)}{0.7896}h_{\pi,t-1} \quad (15)$$

$$h_{yt} = \underset{(2.08)}{0.0000052} + \underset{(3.77)}{0.1281}\epsilon^2_{y,t-1} + \underset{(25.13)}{0.8489}h_{y,t-1} \quad (16)$$

$$h_{\pi y,t} = \underset{(-0.39)}{-0.0221}\sqrt{h_{\pi t}}\ \sqrt{h_{yt}} \quad (17)$$

Notes: This table shows the parameter estimates for the bivariate AR(24)-ccc-GARCH(1,1) model shown by equations (7) to (11). π_t denotes the inflation rate calculated from monthly Wholesale Price Index. y_t denotes the growth rate of output calculated from the monthly Index of Industrial Production of India. $h_{\pi t}$ is the conditional variance of inflation, h_{yt} is the conditional variance of output growth and $h_{\pi y,t}$ is the conditional covariance between inflation and output growth. The sample period evaluated is 1950:1 – 2009:8. The numbers in parentheses are the values of t – statistics. Only significant coefficients of mean equations are shown.

In the results of VAR model of inflation rate and output growth we have shown the significant coefficients only. The variance equations of the results show that the variance of inflation and output growth are time dependent having significant GARCH terms. The results of diagnostic test of standardized residuals of the VAR model are shown in Table 5.

Table 5: Residual Diagnostic

	Mean	Variance	Q (4)	Q (8)	Q^2 (4)	Q^2(8)
$v_{\pi,t}$	0.0240 (0.5290)	0.9996 (0.4993)	7.3219 (0.120)	13.2120 (0.105)	1.7583 (0.780)	3.9419 (0.862)
$v_{y,t}$	0.0139 (0.7148)	1.0018 (0.4793)	2.3393 (0.674)	3.3167 (0.913)	2.1621 (0.706)	4.0967 (0.848)

Q (4) and Q (8) are the Ljung-Box Q statistics for fourth and eighth order serial correlation in the standardized residuals. The values of mean and variance reported in the table are with respect to the hypothesis that mean = 0 and variance = 1. The numbers in parentheses are the *p* values.

We know that an estimated GARCH model should capture all dynamic aspects of the model of the mean and model of the variance. The estimated residuals should be serially uncorrelated and should not display any remaining conditional volatility [Enders (2004)]. From the table we can see that the standardized means and variances of the residuals $v_{\pi,t}$and $v_{y,t}$ are not statistically significantly different from 0 and 1 respectively. We can not be able to reject the null hypothesis that the Q statistics of standardized residuals and squares of standardized residuals of order 4 and 8 are equal to zero. From the results we can say that our models of conditional mean and conditional variance/ covariance are well specified.

Now we proceed to Granger- causality test to know the statistical relationship between average inflation, output growth, inflation uncertainty and output growth uncertainty. The F statistics of Granger- causality test using four, eight and twelve lags are shown in Table 6. In Panel A we consider the Granger- causality from inflation and output growth to uncertainty about inflation and output growth. In Panel B the Granger – causality from uncertainty about inflation and output growth to inflation and output growth is considered. Panel C provides the results of Granger – causality test between inflation and output growth and uncertainties of inflation and output growth.

Table 6
Bivariate Granger-causality tests between inflation, output growth, inflation uncertainty and output growth uncertainty

(A)	$H_0: \pi_t \to h_{\pi t}$	$H_0: \pi_t \to h_{yt}$	$H_0: y_t \to h_{yt}$	$H_0: y_t \to h_{\pi t}$
4 lags	2.861** (+) (0.0228)	0.776 (0.5411)	8.416*** (+) (0.0000)	1.096 (0.3575)
8 lags	5.932*** (+) (0.0000)	0.451 (0.8903)	7.545*** (+) (0.0000)	0.846 (0.5623)
12 lags	4.142*** (+) (0.0000)	0.549 (0.8828)	6.287*** (+) (0.0000)	0.664 (0.7863)
(B)	$H_0: h_{\pi t} \to \pi_t$	$H_0: h_{\pi t} \to y_t$	$H_0: h_{yt} \to y_t$	$H_0: h_{yt} \to \pi_t$
4 lags	6.831*** (–) (0.0002)	0.132 (0.9707)	3.806*** (–) (0.0045)	0.660 (0.6196)
8 lags	4.123*** (–) (0.0000)	0.669 (0.7190)	1.831*(–) (0.0684)	0.669 (0.7190)
12 lags	3.193*** (–) (0.0004)	1.181 (0.2926)	3.023*** (–) (0.0004)	0.473 (0.9308)
(C)	$H_0: \pi_t \to y_t$	$H_0: y_t \to \pi_t$	$H_0: h_{\pi t} \to h_{yt}$	$H_0: h_{yt} \to h_{\pi t}$
4 lags	1.526 (0.1927)	2.506** (–) (0.0410)	0.763 (0.5493)	0.069 (0.9911)
8 lags	2.301** (+) (0.0195)	2.730** (+) (0.0057)	0.804 (0.5990)	0.029 (1.0000)
12 lags	1.055 (0.3958)	2.201*** (–) (0.0104)	1.294 (0.2452)	0.189 (0.9988)

Notes: $\pi_t \to h_{\pi t}$: inflation does not Granger-cause inflation uncertainty; $\pi_t \to h_{yt}$: inflation does not Granger-cause output growth uncertainty; $y_t \to h_{yt}$: output growth does not Granger-cause output growth uncertainty; $y_t \to h_{\pi t}$: output growth does not Granger-cause inflation uncertainty; $h_{\pi t} \to \pi_t$: inflation uncertainty does not Granger-cause inflation; $h_{\pi t} \to y_t$: inflation uncertainty does not Granger-cause output growth; $h_{yt} \to y_t$: output growth uncertainty does not Granger-cause output growth; $h_{yt} \to \pi_t$: output growth uncertainty does not Granger-cause inflation; $\pi_t \to y_t$: inflation does not Grange-cause output growth; $y_t \to \pi_t$: output growth does not Granger-cause inflation; $h_{\pi t} \to h_{yt}$: inflation uncertainty does not Grange-cause output growth uncertainty; $h_{yt} \to h_{\pi t}$: output growth uncertainty does not Granger-cause inflation uncertainty.
F statistics are shown. ***; ** and * denote significance at 0.01, 0.05 and 0.10 levels.
Numbers in parentheses are the p values.
In panel A, a (+) indicates that the sum of the coefficients on lagged inflation (first column) or on lagged output growth (third column) is positive
In panel B, a (–) in first column indicates that the sum of the coefficients on lagged inflation uncertainty is negative. In third column a (–) indicates the sum of the coefficients on lagged output growth uncertainty is negative.
In panel C, a (+) in first column indicates that the sum of coefficients on lagged inflation is negative for 8 lags. In second column the sum of the coefficients on the lagged output growth is negative with 4 and 8 lags, but the sum is positive with 8 lags.

We can see that null hypothesis of no Granger causality from inflation to inflation uncertainty is rejected. The sum of the coefficients of lagged inflation terms is positive. Therefore we have strong evidence that increase in inflation rate leads to increase in inflation uncertainty in India. Again the null hypothesis that output growth does not cause output growth uncertainty is rejected at 1% level of significance. Since the sum of the coefficients of lagged output growth rate is positive we can say that higher rate of growth of leads to higher output growth uncertainty in India. Thus we can say that the first part of Friedman's hypothesis that higher inflation leads to more uncertainty about inflation is valid for India. In Panel B we have found the causality from inflation and output growth uncertainty to inflation and output growth. In the first column of Panel B we see that the null hypothesis of no Granger causality from inflation uncertainty to inflation is rejected and from sign of the sum of the coefficients of the lagged inflation uncertainty we can say that inflation uncertainty reduces the rate of inflation. But form the second column of Panel B we cannot find any effect of inflation uncertainty on the output growth rate. Thus the second argument of Friedman's hypothesis that increase in inflation uncertainty reduces output growth rate is not valid for India. From third column of Panel B we see that output growth uncertainty affects the output growth rate and an increase in output growth uncertainty reduces the output growth rate. This result does not support Black's hypothesis which states that more output growth uncertainty leads to higher output growth. The fourth column of Panel B shows that the hypothesis that output growth uncertainty does not Granger cause inflation cannot be rejected at any conventional level of significance. Thus Deveraux hypothesis that real uncertainty increases the average rate of inflation is not valid for India.

Panel C of Table 6 shows the results of Granger causality test between inflation and output growth and inflation uncertainty and output growth uncertainty. From first column of Panel C we see that no Granger causality from inflation to output growth is rejected at 5% level of significance in case of 8 lags of the estimated equation. We do not have any clear result regarding the effect of output growth on inflation. From second column of Panel C we find that output growth has significant effect on inflation but the direction is not clear. Thus the short run Phillips curve relationship is not strongly supported by our results. We do not find any effect of real uncertainty on nominal uncertainty. Again nominal uncertainty does not have any effect on real uncertainty. Thus our results does not support Taylor's (1979) hypothesis that more inflation uncertainty would be accompanied by less output growth uncertainty.

Conclusion

Using the monthly wholesale price index and index of industrial production as the proxies of inflation and output growth respectively we have constructed a bivariate GARCH model of inflation and growth to find the relationship between inflation, inflation uncertainty and output growth of India. We find strong evidence of positive relationship between inflation and inflation uncertainty and between growth and growth uncertainty. But no statistically significant relationship between inflation uncertainty and output growth rate has been empirically observed. This analysis suggests that price stability must not be the main focus of policy prescription.

In India the rate of inflation was quite moderate. For the period of 1951-52 to 2009-10 the annual average rate of inflation was 6.4%. The coefficient of variation of inflation rate declined from 4.4 less than 1.0 in the subsequent decades. The volatility of output and inflation declined in last three decades in India. Thus inflation uncertainty may not have any adverse effect on productivity and growth for this country. This can explain the statistically insignificant relation between inflation and output growth.

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