International Journal of Economics and Financial Issues

ISSN: 2146-4138

available at http: www.econjournals.com

International Journal of Economics and Financial Issues, 2017, 7(1), 377-386.

The Asymmetric Effects of Real and Nominal Uncertainty on Inflation and Output Growth: Empirical Evidence from Bangladesh

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ABSTRACT

This study examines an empirical analysis of the causal links and volatility spillovers between inflation, output growth and their uncertainties in Bangladesh by utilizing the autoregressive AR(p)-exponential generalized AR conditional heteroscedasticity (EGARCH) model for the period 1993-2014. The study shows that EGARCH version provides the best statistical fit by investigating that volatility is variable and asymmetric than symmetric. The empirical results show an overwhelming support for Friedman-Ball hypothesis that inflationary shocks affect inflation uncertainty positively. Both inflation and output growth generate output uncertainty which is detrimental for real economic activity while nominal uncertainty (real uncertainty) is positively (negatively) affecting output growth. Finally, output uncertainty is reducing inflation uncertainty while there is no effect from the opposite side. Our estimated results suggest that policy makers should adopt dynamic stabilization policies in order to reduce a rise in inflation and to achieve economic stability for stimulating output growth further.

Keywords: Inflation, Output Growth, Uncertainties, Bangladesh, Autoregressive(p)-Exponential Generalized Autoregressive Conditional Heteroscedasticity

JEL Classifications: C32, C51, C52, E10, E30

1. INTRODUCTION

The achievement of sustainable rapid economic growth along with low and stable inflation is the central policy objective of most countries. It has been an issue to achieve such policy targets for the levels inflation and output growth due to many factors that affects macroeconomic performance and hence macroeconomic uncertainty. The relationship between inflation and economic growth is debatable as there is no clear cut and straight forward decision in existing theoretical and empirical studies on the relationships between inflation and economic growth[1]. More importantly, macroeconomists and policy makers have dedicated a great volume of theoretical and empirical research efforts to investigate the welfare costs of inflation as indicated by the price stability as the prime target of world's major central banks. The reason is that higher inflation not only leads towards greater inflation uncertainty but also predicts adverse impact on economic efficiency and growth. Theoretically, there is considerable ambiguity on the impact of inflation on the economic growth as the issue is complicated by the fact that higher inflation affects economic growth through the indirect channel of inflation uncertainty (Friedman, 1977)[2]. Furthermore, the opposite effect may also take place as reported by Cukierman and Meltzer (1986) that in the presence of more inflation uncertainty, the central monetary authorities have an incentive to surprise the public by generating unanticipated inflation with the purpose of output gains.

In addition, both real uncertainty (output growth variability) and nominal uncertainty may affect economic growth and also have

1 Theories and related empirical studies on the relationship between inflation and economic growth have exhibited either no relationship such as Sidrauski (1967), negative relationship such as Barro (1995); Fischer (1993) and positive relationship such as Tobin (1965) and Mallik & Chowdhury (2001).

2 According to him, higher inflation leads to more uncertain inflation which distorts the effectiveness of price mechanism and economic efficiency and results a decline in economic growth.

considerable direct and indirect effect on one another. Although, there is a huge literature on this issue since after 1980s as illustrated by Bernanke (1983); Black (1987); Pindyck (1991); Blackburn and Pelloni (2004) etc., still there is no consensus on the causal links and volatility spillovers of macroeconomic uncertainty on macroeconomic performance. The same is also exhibited in the empirical studies (Carporale and Mckiernan (1997); Grier and Perry (2000); Fountas et al. (2002); Grier et al. (2004); Bredin and Fountas (2009); Fountas (2010) for testing the validity of these theories. Notably, the empirical evidence is still scant and mainly describes G7 data. Considering economic growth and inflation rate as the central subject of macroeconomic policy in many developing and emerging countries, one of the most important targets of any developing country like Bangladesh is to ensure high and sustained economic growth along with low and stable inflation. Thus, a robust evidence in support for the casual dynamics and volatility spillovers between output growth and its uncertainty as well as inflation uncertainty and economic growth would provide a concrete ground for the development of macroeconomic models to empirically consider such multidimensional relationships, specifically in less developing countries.

The study mainly aims to investigate the causal links and volatility spillovers between inflation, inflation uncertainty, output growth and its uncertainty for an ideal economy because little attention has been paid to the empirical evidence on the issue, particularly in the highly volatile economies of South Asia. Despite some progress, like the other emerging and developing economies, Bangladesh is also severely affected by the recent uncertain global economic conditions which obviously pose new challenges to manage price and output growth stability. Historically, as pointed out by Hossain (2015), inflation in the country was moderately high and volatile during the decades of 1950s and 1960s while after independence, it is moderately high and persistently volatile on average under the fixed-pegged exchange rate system and under a managed-floating system since 2003[3]. The country has experienced high inflation in recent years following the recent global financial crises. Overall, in real terms, Bangladesh's economy has grown at relatively low growth rate due to poor infrastructure, political instability, corruption, insufficient energy supplies and lack of policy continuity and implementation of policy reforms. Being a poor, over-populated and inefficiently-governed country, half of the population are employed in volatile-nature agriculture sector. Also, most of the gross domestic product is generated through the service sector such as garments exports and overseas workers remittances whose output is also volatile. Specifically, the continuous diminishing credibility of monetary policy in the country has kept inflation persistently high and volatile which has also adversely affected economic growth. In line to this situation, it is imperative to put some empirical evidence whether the resulting macroeconomic uncertainty brings any cost to macroeconomic performance. To the best of my knowledge, this is the first study to look for the relationships between macroeconomic uncertainty and macroeconomic performance through the recently available monthly data. Unlike the previous studies[4], this study provides much more investigation of the causal links and volatility spillovers among all the four variables through an efficient empirical approach.

This paper contributes to the existing literature in two additional ways: Firstly, different from previous studies and in contrast to the symmetric volatility process governing macroeconomic uncertainty, exponential generalized autoregressive conditional heteroscedasticity (EGARCH) model is utilized to construct conditional variances of inflation and output growth rates. Also, this work is based on the recently available monthly data covering the recent global financial crises, whereas uncertain recent global macroeconomic environment pose new challenges for the macroeconomic policy makers of the country for managing price stability and sustain economic growth. Secondly, unlike the simultaneous estimation procedures, this paper adopts the two-step approach to test the various competing hypotheses regarding inflation-output growth and their uncertainties.

Our empirical findings are very interesting and useful for macroeconomic stabilization policy perspectives. The estimated results show that inflation rate induces uncertainty about both inflation and output growth which impedes real economic activity in the country.

The rest of the study is arranged as follows. In the next section, a brief review of the existing empirical literature is provided while section 3 presents the empirical strategy and estimation procedure for modelling the macroeconomic uncertainty dynamics. Section 4 presents a brief description of data and data sources and section 5 outlines empirical findings and discussion while last section concludes this study.

2. REVIEW OF RELATED LITERATURE

Although the empirical literature on the topic is very dynamic but still controversial and there is no consensus on the existence of major hypotheses illustrating the trade-offs between macroeconomic uncertainty and macroeconomic performance. Some studies including Baillie et al. (1996); Paul et al. (1997); Grier and Perry (1996, 1998, 2000); Berument et al. (2001); Fountas (2001); Hwang (2001; 2007); Fountas et al. (2002); Bhar and Hamori (2003); Conrad and Karanasos (2005); Fountas and Karanasos (2007); Caporale et al. (2012) and Nasr and Ajmi (2014) have thoroughly investigated the volatility dynamics and casual links between inflation and inflation uncertainty in developed and developing countries. Specifically, Daal et al. (2005) and Thornton (2007; 2008) found that inflation uncertainty is caused by higher inflation in Latin American countries. Similarly, Özdemir and Fisunoğlu (2008) evidenced for the existence of famous Friedman hypothesis for Jordan, Philippine and Turkish economies while the study found weak evidence to hold the Cukieman-Meltzer's hypothesis. In contrast, Jiranyakul and Opiela (2010) explored

3 Importantly, lack of policy credibility, presence of large-scale inflows of workers remittances and ready-made garments earnings creates concerns regarding macroeconomic uncertainty in the country.

4 Besides much emphasis on major industrialized countries despite their experience with low to moderate inflation, there is very scarce literature on the issue in developing countries.

the Friedman-Ball and Cukierman-Meltzer's hypotheses through GARCH type models in five major ASEAN countries.

In addition, the early empirical literature on the association between growth uncertainty and output growth consists on the cross-sectional and pooled data with mixed results. For example, Caporale and McKiernan (1996; 1998) evidenced for a positive causal effects of output uncertainty on economic growth (Black's hypothesis) for USA and UK respectively, while Speight and Cm (1999) and Fountas et al. (2002) found no evidence on the relationship between real uncertainty and growth and Henry and Olekalns (2002) supported negative effect. In contrast, Grier and Perry (2000) and Grier et al. (2004) hold positive impact of real volatility on real growth in US economy. There is very scarce literature on the opposite type of causality-from output growth to output uncertainty.

There is abundant literature on the casual links between inflation and economic growth; still there is some controversy on the robustness of the causal relationships between inflation and economic growth. For example, unlike the no effect in 70 countries by Kearney and Chowdhury (1997) for the period 1960-1989, Mallik and Chowdhury (2001) found a significant positive impact of inflation on economic growth in four South Asian countries including Bangladesh. Still, there is a mixed evidence of inflation-growth trade-offs as summarised by numerous studies (Haslag, 1997; Bruno and Easterly, 1998; Gylfason and Herbertsson, 2001; Klump, 2003).

Finally, the empirical evidence on testing the joint effect of macroeconomic uncertainty such as inflation uncertainty and output uncertainty on macroeconomic performance such as inflation and output growth has also been investigated but most of the studies have concentrated on developed countries such as Fountas (2001, 2010); Grier et al. (2004); Fountas et al. (2006); Fountas and Karanasos (2007) and Bhar and Mallik (2010; 2012). Most of these studies have controversial empirical findings and support for different hypotheses governing inflation-output and their uncertainty relationships. As far as developing countries are concerned, there is very scarce literature on the casual links and volatility spillovers between inflation, output growth, nominal uncertainty and real uncertainty. For example, in a very recent study, Rizvi et al. (2014) analysed inflation volatility in Asian perspective by utilizing the quarterly data for ten Asian economies including Pakistan and India through different symmetric and asymmetric GARCH specifications. The study found bi-directional causality between inflation and inflation uncertainty. The study emphasized on the use of asymmetric GARCH models such as EGARCH and GJR-GARCH. Baharumshah and Soon (2014) examined the causal links between inflation, inflation uncertainty and output growth for Malaysia and supported the Friedman-Ball hypothesis and Bernanke's idea while the study also favored the direct and indirect impact of inflation and inflation uncertainty respectively, on economic growth.

Very few studies have examined the inflation-output dynamics and their uncertainties in South Asian economies. Chowdhury (2014) analyzed the causal relationship between inflation and its uncertainty in India and confirmed both Friedman and Cukierman and Meltzer (1986) hypotheses. Javed et al. (2012) provided an evidence for Friedman hypothesis by rejecting the Cukierman and Meltzer (1986) idea for Pakistan while the study also observed the high volatility of inflation persistence in the study area. The only study which partially investigating the inflation-growth links for Bangladesh is the study by Paul (2012) who explored the issue through the bivariate EGARCH in the EGARCH-M model over the period 1976-2009. The study resulted that both inflation and growth adversely affect each other in a lagged manner while Inflation uncertainty and output growth uncertainty appears to be conducive to economic growth, contradicting the well-known Friedman hypothesis and Ramey and Ramey (1995) idea. Astonishingly, the study focuses on controlling inflation rather than inflation uncertainty for ensuring rapid economic growth in Bangladesh.

Thus, owing to the limitations and disagreement of the existing studies on the trade-offs between macroeconomic uncertainty and performance and specifically, the controversial findings of the given empirical literature necessitate the further discovery of the issue with an efficient empirical framework. Importantly, to best of my knowledge, there has been no specific study on this issue in Bangladesh which has historically experienced macroeconomic and political instability and uncertainty. Thus, this study will be the first attempt to assess the causal links and volatility spillovers between inflation-output growth and their related uncertainties in the study area.

3. EMPIRICAL STRATEGY AND ESTIMATION

Most of the empirical economic studies, particularly the various branches of econometrics, especially financial time series analysis examines the effects of uncertainties by modelling the relevant variables as ARCH and GARCH family models. ARCH models were familiarized by Engle (1982) and generalized as GARCH by Bollerslev (1987) by Bollerslev (1986) and Taylor (1979)[5]. These models are popularly used to measure volatility in macroeconomic financial time series. It follows an autoregressive (AR) process along with ARCH and GARCH framework. Also, these models have several features in estimating the causal links among macro-economic uncertainties and economic activities as we can evaluate the risk involved in the relevant economic series through GARCH models. And can provide estimates of the variance of unpredictable innovations in the concerned variables to represent the uncertainty. These models also test the significance of the movement in the conditional variance of a variable in varying time periods. Finally, it allows to forecast confidence intervals as time-varying to achieve more accurate intervals by modelling the variance of the errors and more efficient estimators if heteroskedasticity and other diagnostics tests in the errors are handled properly in the model.

Following the empirical studies by Hasanov and Omay (2011) and Hasanov and Omay (2011) and Mohammad, Baharumshah & Fountas (2012), the mean equations for both output growth and inflation rate are illustrated below.

5 Bollerslev et al. (1992) and Bollerslev et al. (1994), Grier and Perry (2000) and Fountas et al. (2006) for surveys.

$$y_t = \theta_{y0} + \sum_{i=1}^{m} \theta_{yi,} y_{t-i} + \varepsilon_{yt} \qquad \varepsilon_{yt} \sim N(0, h_{yt}) \tag{1}$$

$$\pi_t = \theta_{\pi 0} + \sum_{i=1}^{n} \theta_{\pi i,} \pi_{t-i} + \varepsilon_{\pi t} \qquad \varepsilon_{\pi t} \sim N(0, h_{\pi t}) \tag{2}$$

Where both of the equations represent an autoregressive behaviour and y_t shows output growth rate while π_t is inflation rate and ε_{yt} and $\varepsilon_{\pi t}$ are illustrating the error terms for output growth and inflation rate respectively which are conditionally normal with mean zero and variances h_{yt} and $h_{\pi t}$ respectively.

After specifying the mean equations for both output growth and inflation, we are using the EGARCH approach to investigate the empirical dynamics of the inflation, output growth and their uncertainties in the study area. As GARCH is more parsimonious than ARCH due to the fact that it captures the effect of infinite number of past squared residuals on current volatility and is less likely to violate the non-negativity constraints artificially imposed on ARCH (Bollerslev, 1987). But the simple GARCH model is rejected due to its symmetric response of volatility to positive and negative shocks while a positive inflation shock is more likely to increase inflation volatility via monetary policy mechanism, as compared to negative inflation shock of equal size (Brunner and Hess (1993) and Joyce (1995)) which creates doubts on the symmetric estimates of traditional ARCH and GARCH models and will have to go for asymmetric GARCH model such as EGARCH model, developed by Nelson (1991) to overcome the non-negativity constraints on the parameters by modeling the logarithm of the conditional variance. Following Bhar and Mallik (2003), the variance equation is given as:

$$\ln(h_t) = \omega + \sum_{j=1}^{q} \alpha_j \left| \frac{\varepsilon_t\text{-}j}{\sqrt{h_{t-j}}} \right| + \sum_{j=1}^{q} \gamma_j \frac{\varepsilon_t\text{-}j}{\sqrt{h_{t-j}}} + \sum_{i=1}^{p} \beta_i \ln(h_{t-i}), \ |\beta| < 1 \tag{3}$$

Where ω, α, γ and β are the variance parameters to be estimated and non-zero value of γ indicates the asymmetric effect while the positive value of γ illustrate that high inflation is leading towards high inflation uncertainty and vice versa. In both of the models, the variance specification is used to capture the effects of good news and bad news to model inflation and its volatility and same to output volatility. The EGARCH model is relieving the non-negativity constraint of traditional ARCH by taking log of the conditional variance and allows positive and negative shocks to have different impact on volatility.

After investigating the ARCH effects and then exploring the GARCH effects by utilizing the AR(p) EGARCH approach, the next step is to derive the conditional variances of both output growth and inflation rates to find out the existence of Granger Causality whether inflation, output growth and their uncertainties granger causes one another or not. The Granger causality test is used to determine whether one variable is useful in forecasting (granger causes) the other variable (Granger, 1969). Following the Granger-causality strategy adopted by Kevin and Grier (1998) to capture the lagged effects between the variables of interest, free from the criticism of the potential negativity of the variance and minimizes the number of estimated parameters over the simultaneous-estimation approach as illustrated below:

$$\pi_{\eth i,} = \theta_{\pi 0} + \sum_{i=1}^{k} \beta_{\eth t-i} \pi_{\eth t} + \sum_{i=1}^{k} h + \varepsilon \tag{4a}$$

$$h_{\pi t} = \theta_{\pi 0} + \sum_{i=1}^{k} \theta h_{\pi t-i} + \sum_{i=1}^{k} \beta_{\pi i,} \pi_{t-i} + \varepsilon_{\pi t} \tag{4b}$$

Where "k" symbolizes the lag length and h_t is the uncertainty term. The null hypothesis is that inflation uncertainty (inflation) does not granger cause inflation (inflation uncertainty). While for output equation, we proceed as:

$$y_t = \alpha_{y0} + \sum_{i=1}^{k} \beta_{yi,} y_{t-i} + \sum_{i=1}^{k} \theta h_{yt-i} + \varepsilon_{yt} \tag{5a}$$

$$h_{yt} = \alpha_{y0} + \sum_{i=1}^{k} \theta h_{yt-i} + \sum_{i=1}^{k} \beta_{yi,} y_{t-i} + \varepsilon_{yt} \tag{5b}$$

4. DATA AND DATA SOURCES

Different from most of the previous studies, this study uses the monthly data of output growth rate which is proxied by industrial production index and inflation rate as proxied by consumer price index, obtained from the International Financial Statistics of the International Monetary Fund data base for the period 1993-2014. Given the monthly comparable data, the sample period is constrained by the availability of data. These monthly data series are seasonally unadjusted. In addition, the output growth rate, denoted by y_t and inflation rate as π_t are calculated below to guarantee the stationarity of each variable as follows:

$y_t = \ln(Y_t/Y_{t-1})*100$

$\pi_t = \ln(CPI_t/CPI_{t-1})*100$

5. EMPIRICAL RESULTS AND DISCUSSIONS

For this study, we have selected Bangladesh economy as an interesting example to study the causal links and volatility dynamics of inflation rate and output growth and their uncertainties since Bangladesh as a developing country is historically suffering from high inflation and growth volatility. First, we illustrate the data characteristics and preliminarily diagnostic tests for the existing of ARCH effects. Table 1 shows the summary statistics along with time series properties on both output growth rate and inflation rate. As shown in this table, the average and standard deviation of output growth rate is high as compared to that of inflation rate. Further, the table also shows the long tailed distribution for both inflation rate and output growth as exhibited by the large skewness and kurtosis. Additionally, the Jarque-Bera normality test reveals that both of the data series are non-normally distributed. Thus, the descriptive statistics findings on skewness and excess value of kurtosis indicate non-normal distribution for both inflation and output growth rate as observed in other financial variables. Most importantly, the reported ARCH-LM statistics provide evidence for the existence of ARCH effects in output growth rate as presented by ARCH (8). The significant value of ARCH test provides overwhelming evidence of the presence of ARCH effects. Figure 1 in the appendix exhibits the time plot of both inflation rate and output growth along with their uncertainties for all countries to indicate the volatility of the both series. The figure shows that both inflation and output volatility are indicating the persistence of high volatilities in the given time period.

Further, we also analyze whether or not the unit root existed in our series of interest by applying the widely used augmented Dickey and Fuller (1979, 1981) test (ADF test) and Phillips and Perron (1988) test (PP test) in order to get reliable parameter estimates and statistical inferences. The estimated results are shown in Table 2 for both of the variables in two cases as level and intercept and with a constant term and trend. The results shows that the null hypothesis of unit root is easily rejected in all cases by both ADF and PP tests, indicating that both of the series are stationary at level. So, we conclude that our series are stationary at level at two robust tests.

5.1. Estimates of AR(p) EGARCH Models

The decision about the lag order in empirical model is based on a number of criteria. The lag order for AR part in both output growth rate and inflation rate is determined by information criteria such as minimum Akaike information criteria and the existence of white noise error. The presence of auto correlation in the residuals of auto regressive model is tested by Breusch-Godfrey test and Ljung-Box Q statistics. Based on model selection criteria and residual diagnostic tests in the form of Ljung-Box Q statistic and Ljung-Box squared of Q statistic, we have chosen AR(5) for the mean equations of both output growth and inflation rate. As our model contains AR term such as the existence of the lagged dependent as endogenous variable which appeals to the application of maximum likelihood estimates which are asymptotically efficient (Davidson and MacKinnon, 1993).

In the first step of estimation process, we checked whether there is auto correlation and ARCH effect in our series of interest as output growth rate and inflation rate by running simple OLS and then testing the residual for both specifications. After confirming the auto correlation and ARCH effects, we next proceed to auto regressive GARCH specifications. We have specified the EGARCH(1,1) model as adequate to model the causal links and volatility dynamics of inflation, output growth and their uncertainties. The estimated EGARCH model parameters are presented in Table 3, whereas panel A presents the estimated results of mean output growth and inflation equations while the variance equations for both of the series are presented at panel B of this table. The results of mean equations show that the lagged output values are highly negatively significant while lagged inflation is having a mix response to current inflation, indicating inflation inertia. The lagged value of GARCH term is highly positively significant for output growth equation while it does not hold true in case of ARCH effects for output equation. The sum of ARCH and GARCH term is near to one, indicating that current information remains important for the forecast of the conditional variance. In addition, the variance inflation equation exhibits negative response of lagged conditional shocks to inflation uncertainty while both of the series support the asymmetric behaviour, confirming the use of EGARCH specification for modelling the trade-offs between macroeconomic uncertainty and macroeconomic performance. Consequently, there is a positive significant asymmetric volatility for both output growth and inflation equations and consistent with the empirical study by Paul (2012) for the same area that positive and negative shocks have different effects on macroeconomic uncertainty.

After estimating the EGARCH models for both output and inflation, we perform the residual diagnostic tests to judge whether the estimated model capture the joint distribution of the residuals reasonably well. The residual diagnostic tests for the conditional mean and variance model are performed at panel C to show the validity of the estimated parameters and the significance of the joint distribution of disturbances. Comfortably, the diagnostic tests show that there is no serial auto-correlation and serial dependence as well as heteroscedasticity in the model. The ARCH test is unable to reject the null of no ARCH effects which means that there is no further ARCH effects in the series. The estimated results for standardized residuals and squared standardized residuals as pointed out by three different lag orders such as 1, 4 and 8 hold satisfied for both of the series except of output growth equation at lag 8 while ARCH tests reject the null of ARCH effects for all

Table: 1 Descriptive statistics and preliminary diagnostic tests

Var(s)	Mean	Med	Maximum	Minimum	Standard deviation	Skew	Kurt	Jarque Bera	ARCH (8)	ARCH (12)
π_t	0.5277	0.3757	4.1156	−2.4641	0.8380	0.3267	4.8225	40.1404 (0.0000)	0.3961 (0.9221)	0.3630 (0.9749)
y_t	0.7021	1.1236	27.262	−25.5973	7.6581	−0.1956	3.9509	11.4098 (0.0033)	2.0056 (0.0943)	0.7126 (0.7386)

ARCH (m) is the m^{th} order test for auto regressive conditional heteroscedasticity. Figures in parentheses show the probability values

Table 2: Unit root and stationarity tests results

Var(s)	ADF		PP	
	Constant	Constant and trend	Constant	Constant and trend
π_t	−11.5304***(0)	−11.5439***(0)	−10.9565***	−10.9521***
y_t	−19.964***(0)	−19.936***(0)	−39.332***	−41.994***

ADF: Augmented Dickey and Fuller, PP: Phillips and Perron countries at lag 8 and lag 12. However, the normality assumption does not hold for the estimated series in both equations.

5.2. Estimated Results of Granger Causality between Macroeconomic Uncertainty and Macroeconomic Performance

Following the literature and to explore the causal links and relationships of inflation, output growth and their uncertainties, we carried out the Granger causality tests at different lags levels to test whether our results are robust at different lag lengths. Table 4 presents the estimated results of Granger causality tests to test the empirical relationships between inflation, output growth and their concerned uncertainties as well as the signs of the sum of lagged coefficients.

The first four rows document the estimated results of the casual relationships between inflation, inflation uncertainty and output

Table 3: The estimated results of AR(p)-EGARCH Model

Panel A: Estimation of the mean equations			
Mean output growth equation		**Mean inflation equation**	
AR(p)	**AR(5)**	**AR(p)**	**AR(5)**
Constant	2.3663*** (0.4051)	Constant	0.4656***(0.0552)
y_{t-1}	−0.4349***(0.0556)	π_{t-1}	0.3154***(0.0480)
y_{t-2}	−0.3476***(0.0549)	π_{t-2}	−0.0840 (0.0656)
y_{t-3}	−0.4810***(0.0541)	π_{t-3}	−0.0501 (0.0580)
y_{t-4}	−0.4639***(0.0600)	π_{t-4}	−0.1714***(0.0585)
y_{t-5}	−0.1723***(0.0591)	π_{t-5}	0.0595 (0.0652)
Panel B: Estimates of the variance equations			
Variance equation for output growth		**Variance equation for inflation rate**	
ω	0.0397 (0.0500)	ω	−0.0966 (0.1496)
α	0.0102 (0.0352)	α	−0.3297*(0.1993)
γ	0.1571***(0.0440)	γ	0.1459*(0.0878)
β	0.9888***(0.0112)	β	0.3548 (0.3314)
Panel C: Residuals diagnostics of output equation			
Output growth equation		**Inflation equation**	
Q_1	0.1322 [0.716]	Q_1	0.1779 [0.673]
Q_4	0.5788 [0.965]	Q_4	0.3189 [0.989]
Q_8	25.482 [0.001]	Q_8	8.4803 [0.388]
Q_1^2	0.0049 [0.944]	Q_1^2	0.0943 [0.759]
Q_4^2	0.4068 [0.982]	Q_4^2	0.6484 [0.958]
Q_8^2	4.2436 [0.835]	Q_8^2	8.1274 [0.421]
ARCH(8)	0.5436 [0.8228]	ARCH(8)	1.0493 [0.3998]
ARCH(12)	0.6425 [0.8045]	ARCH(12)	0.9470 [0.5008]
AIC	6.5535	AIC	2.4009
SIC	6.6928	SIC	2.5409
LL	−822.3030	LL	−292.5174
Jurque-Bera test	12.6848 [0.0017]	Jurque-Bera test	39.1790 [0.0000]

Figures in parentheses are the Standard error values. Q_p and Q_p^2 are the ρ^{th} - order Ljung-Box test statistics for correlation in standardized residuals and squared standardized residuals, respectively. AIC, SC and LL shows the Akaike information criterion, Schwarz criterion and maximum log-likelihood criterion respectively. ARCH (m) is the m^{th} - order auto regressive conditional heteroscedasticity. Jarque-Bera is the normality test. EGARCH: Exponential generalized autoregressive conditional heteroscedasticity, AIC: Akaike information criteria

Table 4: Granger causality tests among inflation, output growth, nominal uncertainty and real uncertainty

Direction of causality	Lag-4	Lag-8	Lag-12
$\pi_t \rightarrow h_{\pi t}$	47.3703 (0.0000) [+]	46.7719 (0.0000) [+]	51.7530 (0.0000) [+]
$h_{\pi t} \rightarrow \pi_t$	3.5854 (0.4650)	5.4452 (0.7091)	7.2246 (0.8424)
$\pi_t \rightarrow h_{yt}$	2.2672 (0.6867)	13.6634 (0.0910) [+]	18.2339 (0.1088)
$h_{yt} \rightarrow \pi_t$	6.7350 (0.1506)	5.4110 (0.7129)	6.6026 (0.8827)
$h_{\pi t} \rightarrow y_t$	2.0763 (0.7217)	16.7104 (0.0333) [+]	18.5950 (0.0988) [+]
$h_{yt} \rightarrow y_t$	8.7138 (0.0687) [−]	71.4937 (0.0000) [−]	16.6189 (0.1645)
$y_t \rightarrow h_{yt}$	1511.104 (0.000) [+]	3798.816 (0.000) [+]	3346.296 (0.000) [+]
$y_t \rightarrow h_{\pi t}$	5.8803 (0.2083)	2.6468 (0.9545)	10.2136 (0.59720
$\pi_t \rightarrow y_t$	4.2789 (0.3696)	20.3922 (0.0089) [+]	19.8295 (0.0704) [+]
$y_t \rightarrow \pi_t$	6.8982 (0.1414)	7.7361 (0.4597)	7.9220 (0.7912)
$h_{yt} \rightarrow h_{\pi t}$	11.4697 (0.0218) [−]	3.9833 (0.8586)	8.4507 (7490)
$h_{\pi t} \rightarrow h_{yt}$	2.2934 (0.6820)	8.6808 (0.3699)	12.8882 (0.3772)

π_t and y_t denotes inflation and output growth respectively while $h_{\pi t}$ and h_{yt} stand for inflation uncertainty and output uncertainty, respectively. $\pi_t \rightarrow h_{\pi t}$ means inflation granger causes inflation uncertainty. The numbers in the first row give the different lag structure and figures are χ^2 statistics while the numbers in the parentheses are the P values. The sign in square brackets shows the sign of causality such that a + (−) indicates that the sum of the lagged coefficients of the causing variable is positive (negative) uncertainty while the middle four rows illustrate the Granger causality results for testing the relationships between output growth, inflation uncertainty and output growth uncertainty. The last four rows exhibit the estimated results for the causal links between inflation, output growth and their uncertainties. The first row of table tests the Friedman's idea that high inflation is leading towards to inflation uncertainty. Our estimated results strongly support this idea by all lags and is consistent with the existing empirical studies (Mohd et al. (2012) for ASEAN countries; Heidari et al. (2013) for Iran; Baharumshah and Soon (2014) for Malaysia; Rizvi et al. (2014) for ten Asian countries including south Asian countries. Next, the estimated results of granger causality of inflation uncertainty on inflation rate show that there is no significant effect of inflation uncertainty on inflation in Bangladesh and consistent with the empirical results of Paul (2012) who used quarterly data and EGARCH-M approach for Bangladesh. This further indicates that there is no evidence of positive or negative effect of inflation uncertainty on inflation as theorised by Cukierman and Meltzer (1986) or Holland (1995) respectively. In addition, the estimated results of the causal relationship of inflation and output uncertainty explain that inflation rate is inducing output uncertainty in case of Bangladesh at lags 8 only which is in support of Friedman-Ball hypothesis and Okun's (1971) assumption that higher inflation induces inflation uncertainty which is generating output uncertainty as Okun (1971) postulated. The fourth row checks the causal relationships between output uncertainty and inflation rate such that there is no evidence of existence for the causal relationship between output uncertainty and inflation rate for Bangladesh which does not support the hypotheses of positive impact by Devereux (1989) and Cukierman and Gerlach (2003) and that of negative impact by Taylor (1979) and Cukierman and Meltzer (1986).

The estimated results also test the causality running from inflation uncertainty to output growth which holds positively for Bangladesh and support Dotsey and Sarte (2000) hypothesis that owing to inflation uncertainty, output growth improves due to risk aversion and pre-cautionary savings. This is in contrast to Friedman (1977) that inflation uncertainty reduces output growth. The estimated results are in line to recent study by Paul (2012) that inflation uncertainty appears to be boosting economic growth in Bangladesh. Importantly, the estimated results provide strong support of negative relationship between output uncertainty and output growth and support the famous Ramey and Ramey (1995) hypothesis in contrast to Black (1987) idea of positive impact of output growth uncertainty on growth. The estimated results also highlight the causal links between output growth and output uncertainty. Interestingly, there is a strong support for positive relationship between output growth and output uncertainty which provides an evidence for the existence of Fountas and Karanasos (2006) conjecture that output growth is promoting real uncertainty in Bangladesh. There is no support for the causal links between output growth and inflation uncertainty in the study area.

Finally, we report the casual links among inflation, output growth and their uncertainties. The estimated results reveal that inflation induces output growth as already pointed out by the empirical study by Mallik and Chowdhury (2001) for four south Asian countries including Bangladesh through annual data. There is no empirical evidence that output growth have any effect on inflation while there is a negative relationship between output uncertainty and inflation uncertainty at lags4 which support Fuhrer's (1997) theory and contradicts with Devereux (1989) idea of positive impact of output uncertainty on inflation uncertainty. Lastly, the estimated results confirm that inflation uncertainty is not causing output uncertainty in Bangladesh. Consequently, it is derived that inflation rate induces uncertainty about both inflation and output growth which impedes real economic activity in the country.

6. CONCLUSION AND POLICY RECOMMENDATIONS

This study has examined the causal links between inflation, output growth and their uncertainties an ideal economy, experiencing high macroeconomic instability and uncertainty. The study also attempt to empirically determine whether volatility of inflation and output growth rate is symmetric or asymmetric. Specifically, the study tries to test the various hypotheses developed by Friedman (1977), Cukierman and Meltzer (1986), Pindyck (1991), Ball (1992), Holland (1995) and Dotsey and Sarte (2000) by the significance of various parameters for Bangladesh economy.

The empirical results shows that there is an overwhelmingly support for well-known Friedman-Ball hypothesis that inflation rate is leading to inflation uncertainty in Bangladesh. Thus, there is no evidence for the existence of Cukierman and Meltzer's (1986) and Holland's (1995) hypotheses. The study indicates that both inflation and output growth is leading towards output variability, implying Friedman-Ball and Okun's (1971) and Fountas and Karanasos (2006) conjectures respectively. Inflation uncertainty (output uncertainty) is positively (negatively) affecting output growth and support the Dotsey and Sarte (2000) and Ramey and Ramey (1995) hypotheses. The results suggest that higher inflation improves output growth while there is no casual links between nominal and real uncertainty except that output uncertainty is negatively affecting inflation uncertainty and support Fuhrer's (1997) theory. It is worth to mention that some of the effects and even mixed effects can be ascribed due to the nature and structure of the economy and macroeconomic policies. The other macro-economic variables like interest rate, exchange rate and investment etc. also play strong role in determining the price and output levels and their uncertainties.

The empirical findings of this study have not only important theoretical implications for the policy makers to expectations formations in order to better understand the macroeconomic uncertainty process but also several important dimensions of policy implications can be derived from this study regarding inflation, its uncertainty, output growth and real uncertainty and their causal interactions. In this study, the empirical strong evidence that inflation raises future inflation uncertainty necessitates the need for better monetary stabilization and demand for targeting inflation by independent authority of central bank. More importantly, the current macroeconomic environment of the country (where inflation is increasing continuously), call for more dynamic stabilization policy implication for central banks to deal with high inflation along with protection to economic growth. This study detects and investigates the asymmetry of inflation and output volatility which has been ignored by most of the previous studies. These asymmetries have important policy implications for inflation targeting stabilizations policies. The causal links between inflation, output growth and their uncertainties also augment the policy makers to explore the desirable policy frame work. The study also tests the validity of various hypotheses and point out the existing phenomenon in the study area. This study suggests the use of monetary policy for achieving multiple policy objectives such as reducing inflation and its volatility after considering economic growth. However, the study calls for empirical work needed on uncertainty of interest rate and exchange rate in order to better understand the causal direct and indirect interactions of inflation and output growth and their uncertainties. Further research may also require to examine the possible structural breaks and non-linearities of these variables and to augment the findings with other GARCH family models.

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APPENDIX

Figure 1: Inflation, output growth, inflation uncertainty and output uncertainty: 1993-2014