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Inflation, Growth and their Uncertainties: A Bivariate GARCH Evidence for Iran

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Abstract

Using a bivariate GARCH model, we investigate the causal relationships between inflation, growth, inflation uncertainty (nominal uncertainty) and output uncertainty (real uncertainty) for seasonally adjusted quarterly data in Iran. Our results indicate that increased inflation is associated with higher nominal uncertainty. Further, we found that higher output uncertainty increases both inflation and growth. Increased growth, in turn, is associated with higher real uncertainty. We found no strong evidence in favor of other causal relationships which we have tested. These results support the argument of a price stability objective for the monetary authority. To mitigate the harmful effects of real uncertainty, Iran should take policy measures to withstand adverse domestic and external shocks and lessen their exposure to the volatility.

Keyword: Inflation, Output growth, Uncertainty, Granger-causality, Bivariate GARCH.

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1- Introduction

One of the most important determinants of the real costs of inflation is inflation uncertainty. According to Friedman (1977), a rise in the average rate of inflation is associated with more uncertainty about the rate of inflation, economic inefficiency, and a lower output. Given the destabilizing effect on output caused by high average inflation, the monetary authority might have an incentive to respond to more inflation uncertainty by contractionary monetary policy. Therefore, Central Banks whose overriding objective is price stability and which are independent from the political process would be expected to tighten if evidence of a rise in average inflation is available.

Using a bivariate Generalized Autoregressive Conditional Heteroskedasticity (GARCH) model that includes output growth and inflation, we want to analyze the above issues empirically for Iran. Since there is no data for real and nominal uncertainties our estimated model is used to generate the conditional variances of inflation and output growth as proxies of inflation and output growth uncertainty, respectively, and perform Granger-causality tests. This model allows us to examine the causal relationships between inflation and output growth, on the one hand, and uncertainty about inflation and output growth, on the other hand.

Macroeconomic theory provides us with the predicted effects for these relationships which are discussed in Section 2. Our econometric model is represented in section 3. The reports and discussion of our results is the topic of section 4. Finally, Section 5 summarizes our main conclusions.

2- Theory

Economic theory supplies the economic interpretation for the predicted relationships between nominal (inflation) uncertainty, real (output growth) uncertainty, output growth, and inflation. The total number of testable hypotheses regarding bidirectional causality among these four variables is 12. Here we present some of the most well-known theories with an especial classification.

2-1-Theories about Relationship between Inflation and output Growth

The relationship between inflation and growth has become an intense research branch since the Mundell-Tobin effect was first described. In this earlier formulation the connection between economic growth and inflation comes out from a framework that has only two assets: money and capital. In steady state an increase in the rate of return of money implies a decrease in return of the other assets (they are assumed to be substitutes in the household portfolios). In other words, an increase in inflation positively impacts capital accumulation and consequently growth.[1] But this result has systematically been challenged in empirical and theoretical papers. For instance, Jones and Manuelli (1995) and De Gregorio (1993) points out that inflation is a tax on capital in models with cash-in-advance requirement for investment and, as a consequence, impacts growth negatively. Similarly, most of the empirical papers have shown a negative relationship between these two variables but without a theoretical agreement about the reasons for the negative relation.[2] Anyway, in economies with high uncertainty in growth and inflation the simple relationship between those two variables may be unsatisfactory.

2-2- Theories about Relationship between Inflation and Inflation Uncertainty

The most well known hypotheses are the ones that relate inflation to inflation uncertainty and output growth. Friedman (1977) provides an intuitive argument that higher inflation leads to more uncertainty about inflation. Ball (1992), using an asymmetric information game, offers a formal derivation of Friedman’s hypothesis that higher inflation causes more inflation uncertainty.

1- See Walsh (1998) for a survey of the models used to explain this relation.

2- For instance, Bruno and Easterday (1998) show that high inflation economies are more susceptible to find negative relations between growth and inflation but that in cross-section analysis this relation seems to be ambiguous or even inexistent. The reason is that rapid and huge increases and decreases in inflation has a boom effect on growth which is not captured in mild inflationary processes. However, Barro (1996) uses another data set and find a negative cross section relation between the two variables in fairly general contexts using arguments similar to Jones and Manuelli (1995).

Some other analyses are also presented that according to them higher inflation reduces inflation uncertainty. For example Pourgerami and Maskus (1987) show that an increase in inflation will drop inflation uncertainty. They claim that in the case of increasing inflation more resources would be allocated to inflation forecasting and this would cause lower inflation uncertainty. More formal analyses of this effect is presented by Ungar and Zilberfarb(1993).

The analysis of causal effect of inflation uncertainty on inflation in the theoretical macro literature is presented by Cukierman and Meltzer (1986). Using the well-known Barro– Gordon model, Cukierman and Meltzer show that an increase in uncertainty about money growth and inflation will raise the optimal average inflation rate because it provides an incentive to the policymaker to create an inflation surprise in order to stimulate output growth. Hence, the prediction of the Cukierman and Meltzer analysis is that higher inflation uncertainty causes higher inflation. Holland (1995) claims in the presence of a stabilization motive on the part of the policymaker, an increase in inflation uncertainty will invite a tight monetary policy response and a lower average inflation rate in order to minimize the real costs of inflation uncertainty. This is more likely to happen under Central Bank independence and a commitment to long-run price stability. Hence, the prediction of the stabilization hypothesis and Cukierman–Meltzer theory are in opposition to each other, i.e., a negative causal effect of inflation uncertainty on inflation.

2-3- Theories about Relationship between Inflation Uncertainty and Real Growth

Friedman (1977) argues that higher inflation uncertainty distorts the effectiveness of the price mechanism in allocating resources efficiently and, hence, causes a negative output effect, i.e., a negative causal effect of inflation uncertainty on real growth. The effect of output growth on inflation uncertainty would be expected to be positive. As higher output growth is associated by higher inflation (the short-run Phillips curve), the uncertainty about inflation would also increase, according to the Friedman’s hypothesis.

On the other hand Dotsey and Sarte (2000) believe that inflation uncertainty can lead to higher growth. Using a cash-in-advance model (which precautionary saving and risk averseness are of its characteristics), they show that by increasing the variability of money supply and as a consequence inflation, money returns decreases. Following this real money demand, and as a result, consumption decreases. This decreased consumption leads to higher precautionary saving. Finally saving funds fellow thorough out the investment will raise output and economic growth.

2-4- Theories about Relationship between Output Growth Uncertainty, Inflation and Output Growth

We now take a look at the bidirectional causality between output growth uncertainty, on the one hand, and inflation and output growth, on the other hand. According to Deveraux (1989), real uncertainty increases the average rate of inflation. Using the Barro–Gordon model, Deveraux(1989) shows that higher output growth uncertainty reduces the optimal amount of wage indexation and induces the policymaker to engineer more inflation surprises in order to obtain favorable real effects.

Ramey and Ramey (1991) suppose a simple general equilibrium model in which firms make technology commitments in advance, e.g., the determination of the scale of a new factory or the size of the attached labor force. Each technology corresponds to a different minimum efficient scale and in the absence of economic fluctuations; firms would choose their technology to bring minimum efficient scale into line with the equilibrium output level. However, if growth volatility (higher economic instability) increases, equilibrium output levels may depart from minimum efficient scale and firms may end up with average costs above the minimum level. Thus, volatility causes firms' production plans to be suboptimal ex post and as a consequence, growth uncertainty diminishes the average real growth.

According to Black (1987), more output uncertainty should be associated with higher output growth. His argument is that investment in a more risky technology would be followed by higher average output growth. The reverse causality effects (from inflation and output growth to output growth uncertainty) are expected to be as follows: according to Friedman, an increase in the average rate of inflation should lead to more inflation uncertainty. Furthermore, according to Taylor’s (1979) result of a trade-off between inflation uncertainty and output growth uncertainty, (the so-called

Taylor curve) more inflation uncertainty would be accompanied by less output growth uncertainty. In summary, more inflation leads to lower real uncertainty.

One would expect a positive causal effect of output growth on output growth uncertainty. As output growth rises and an inflationary pressure is created, the monetary authority responds by a monetary contraction which reduces the average rate of inflation and inflation uncertainty and, hence, increases real uncertainty. Table 1 shows these theories in summary.

Table 1: Casual relationship between the variables

Hypothesis	Sign
Inflation causes output growth	
Mundell-Tobin effect, Bruno and Easterday (1998)	+
Jones and Manuelli (1995),De Gregorio (1993) and Barro (1996)	-
Inflation causes inflation uncertainty	
Friedman(1977), Ball (1992)	+
Pourgerami and Maskus (1987)	-
Inflation uncertainty causes output growth	
Friedman (1977)	-
Dotsey and Sarte (2000)	+
Inflation uncertainty causes inflation	
Cukierman and Meltzer (1986)	+
Holland (1995)	-
Inflation uncertainty causes growth uncertainty	
Taylor (1979)	-
Growth uncertainty causes inflation	
Deveraux(1989)	+
Growth uncertainty causes output growth	
Black (1987)	+
Ramey and Ramey (1991)	-

3- A Bivariate GARCH Model of Inflation and Output Growth

We use a bivariate GARCH model to simultaneously estimate the conditional means, variances, and covariances of inflation and output growth which has the following specification:

$$\pi_t = \varphi_{\pi 0} + \sum_{i=1}^{n} \varphi_{\pi\pi,i} \pi_{t-i} + \sum_{i=1}^{m} \varphi_{\pi g,i} g_{t-i} + \varepsilon_{\pi t} \qquad (1)$$

$$g_t = \varphi_{g0} + \sum_{i=1}^{n'} \varphi_{g\pi,i} \pi_{t-i} + \sum_{i=1}^{m'} \varphi_{gg,i} g_{t-i} + \varepsilon_{gt} \qquad (2)$$

$$H_t = \mathbf{C}'\mathbf{C} + \sum_{k=1}^{K} \sum_{i=1}^{q} \mathbf{A}'_{ki} \varepsilon_{t-i} \varepsilon'_{t-i} \mathbf{A}_{ki} + \sum_{k=1}^{K} \sum_{j=1}^{p} \mathbf{B}'_{kj} H_{t-j} \mathbf{B}_{kj} \qquad (3)$$

Where π_t and g_t denote the inflation rate and real output growth, respectively. Define the residual vector ε_t as $\varepsilon_t = (\varepsilon_{\pi t}, \varepsilon_{gt})'$. We assume that ε_t is conditionally normal with mean vector 0 and covariance matrix H_t. That is $(\varepsilon_t | \Omega_{t-1}) \sim N(0, H_t)$, where Ω_{t-1} is the information set up to time t-1. The third equation shows the variance-covariance process where C, A_{ki} and B_{kj} are $n \times n$ parameter matrices with C triangular. K determines the generality of the process. This specification is called BEKK model and is due to Engle and Kroner (1995). Its improvement upon other models of this class is that the representation for the H_t matrix guarantees it is positive definite for all values of t and, additionally, we have fewer parameters to estimate compared to traditional VEC representations.[1] For the bivariate case with K=1, q=1 and p=1 we have:

1- See Bollerslev et al. (1994) and Engle and Kroner (1995) for more details.

$$\mathbf{\Sigma}_t = \begin{pmatrix} h_{\pi\pi,t} & h_{g\pi,t} \\ h_{\pi g,t} & h_{gg,t} \end{pmatrix} = \begin{pmatrix} c_{11} & 0 \\ c_{21} & c_{22} \end{pmatrix}' \begin{pmatrix} c_{11} & c_{21} \\ 0 & c_{22} \end{pmatrix} +$$

$$\begin{pmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{pmatrix}' \begin{pmatrix} \varepsilon^2_{\pi t-1} & \varepsilon_{\pi t-1}\varepsilon_{gt-1} \\ \varepsilon_{gt-1}\varepsilon_{\pi t-1} & \varepsilon^2_{gt-1} \end{pmatrix} \begin{pmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{pmatrix} \tag{4}$$

$$+\begin{pmatrix} b_{11} & b_{12} \\ b_{12} & b_{22} \end{pmatrix}' \begin{pmatrix} h_{\pi,t-1} & h_{\pi g,t-1} \\ h_{g\pi,t-1} & h_{gg,t-1} \end{pmatrix} \begin{pmatrix} b_{11} & b_{12} \\ b_{12} & b_{22} \end{pmatrix}$$

Where $h_{\pi\pi,t}$ and $h_{gg,t}$ denote the conditional variances of the inflation rate and output growth, respectively, and $h_{g\pi,t-1}$ is the conditional covariance between $\varepsilon_{\pi t}$ and ε_{gt} .

The estimation method will be quasi-maximum likelihood, proposed by Bollerslev and Wooldridge (1992). Their estimator is consistent for non-normality of the residuals, which is a common feature of this kind of models. The estimation of Eqs. (1), (2) and (4) will follow the numerical optimization algorithm proposed by Berndt et al. (1974) and known as BHHH.

In empirical work, we estimate several bivariate specifications (over 160 specifications with different restrictions on the C, A and B matrices) for inflation and output growth to choose the best one. To choose the best specification we use Bayesian Information Criteria (BIC).

We measure inflation and output uncertainty by the estimated conditional variances of inflation and output growth, respectively. We then perform Granger causality tests to examine the bidirectional causal relationships between the four variables. We have chosen the Granger causality approach (see also Grier and Perry, 1998) over the simultaneous-estimation approach for three reasons. (1) It allows us to capture the lagged effects between the variables of interest. (2) The simultaneous approach is not subject to the criticism of the potential negativity of the variance. (3) The Granger causality approach minimizes the number of estimated parameters.

4- Results and discussion

In our empirical analysis, we use the Consumer Price Index (CPI) and the Gross Domestic Product (GDP) of Iran to obtain inflation and output growth, respectively. The data have quarterly frequency and range from 1367:1 to 1384:4. Since the data are seasonally adjusted, there is no need to consider the seasonal effects into the model. Allowing for differencing implies 71 usable observations. Inflation is measured by the quarterly difference of the log CPI:

$$\pi = d(\log(CPI))$$

Real output growth is measured by the quarterly difference in the log of the GDP:

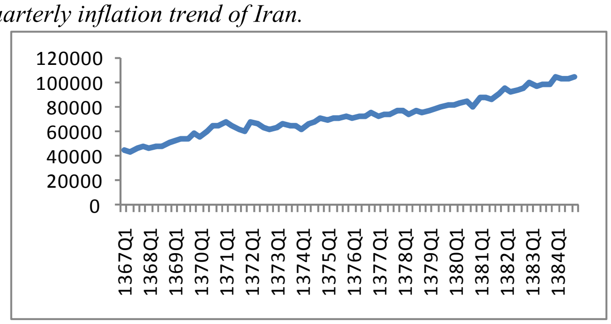
$$g = d(\log(GDP))$$

We test for the stationarity properties of our data using the Augmented Dickey–Fuller (ADF) and Phillips–Perron (PP) tests. The results of these tests for two variables of log(GDP) and log(CPI) (with trend and without trend), are reported in Table 2. According to ADF and PP tests for both cases of with and without trend, it is clear that log(GDP) is not stationary in level but is stationary in first difference. So these tests imply that we can treat the growth rate of GDP as stationary processes. For log(CPI) according to both ADF and PP, we see that it is not stationary (for both cases of with and without trend), but by differencing once, according to PP, for both cases of with and without trend, we can treat the inflation as stationary process. According to ADF test we see that for the case of without trend the inflation is not stationary, but for the case of with trend it is stationary in 5% level of significance. Since the log(CPI) series has trend as depicted in figure 1, we treat the first difference of log(CPI) or in other words, inflation rate, as stationary process as suggested by the PP tests. Figure 1 depicts the quarterly trend of CPI and inflation. Figure 2 shows the quarterly trend of GDP and output growth.

Table 2: Unit root test

		Log(CPI) (Level)	Log (CPI) (First difference)	Log(GDP) (Level)	Log(GDP) (First difference)
ADF (without trend)	Critical value at 5% Calculated statistic P-Value	-2.904 -1.99 0.29	-2.906 -1.92 0.32	-2.905 -1.141 0.695	-2.905 -7.392 0.000
ADF (with trend)	Critical value at 5% Calculated statistic P-Value	-3.4763 -1.077 0.925	-3.4763 -3.534 0.04	-3.474 -3.485 0.049	-3.477 -7.390 0.000
PP (without trend)	Critical value at 5% Calculated statistic P-Value	-2.901 -1.395 0.580	-2.901 -6.058 0.000	-901 -1.516 0.520	-2.904 -12.475 0.0001
PP (with trend)	Critical value at 5% Calculated statistic P-Value	-3.471 -0.496 0.962	-3.472 -6.199 0.000	-3.474 -3.309 0.073	-3.475 -15.626 0.0001
	Stationary state	Non-stationary	Stationary	Non-stationary	Stationary

a) Quarterly inflation trend of Iran.



b) Quarterly inflation trend of Iran.

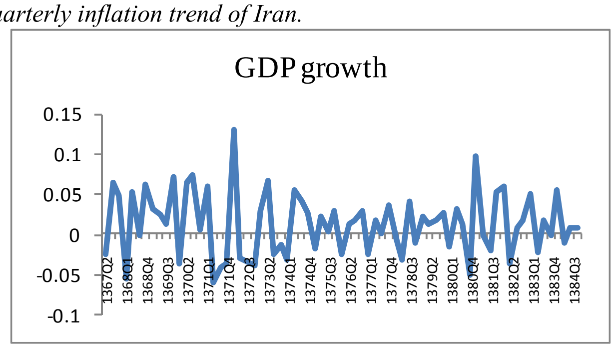
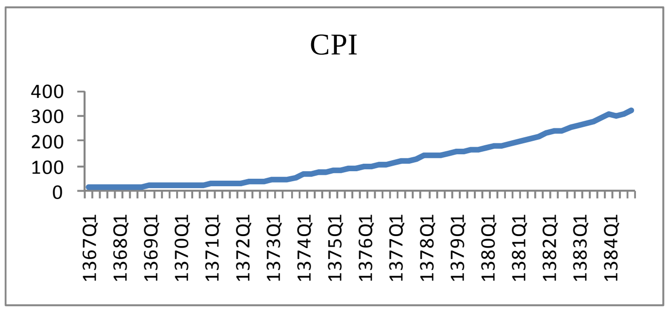


Figure 1: Quarterly CPI trend of Iran.

a) Quarterly GDP trend of Iran



b) Quarterly output growth trend of Iran.

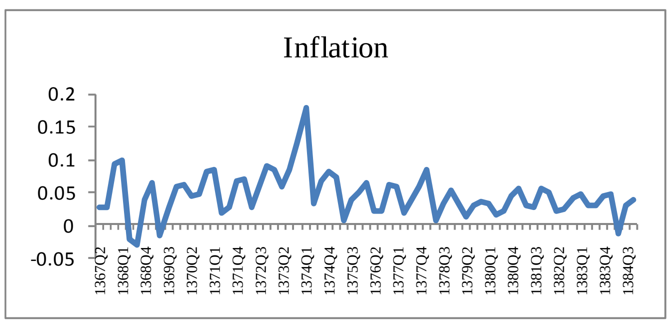


Figure 2: Quarterly GDP trend of Iran.

Table 2 reports estimates of the Bivariate-BEKK-GARCH model of Section 3. The conditional mean for inflation and output growth are reported in Eqs. (1) and (2) of Table 3 respectively. All of the coefficients except the coefficient of g_{t-3} are significant at 0.01 level of significance and the coefficient of g_{t-3} is significant at 0.1 level. The estimate of the conditional variance-covariance matrix is reported in Eq. (3) of Table 3. The ARCH parameters are significant at the 0.01 level.

Table 3: Estimates of the Bivariate-BEKK-GARCH model of Section 3

1	$\pi_t = 0.0197 + 0.4675\,\pi_{t-4}$ (5.1306) (6.38)
2	$g_t = 0.023 - 0.30582\,g_{t-1} - 0.31942\,g_{t-2} - 0.20279\,g_{t-3}$ (5.261) (-4.528) (-2.5123) (-1.867)
3	$H_t = \begin{bmatrix} h_{\pi\pi t} & h_{\pi g t} \\ h_{g\pi t} & h_{ggt} \end{bmatrix}$ $= \begin{bmatrix} \underset{(4.884)}{0.000793} & 0 \\ 0 & \underset{(3.6208)}{0.00027} \end{bmatrix}' \begin{bmatrix} \underset{(4.884)}{0.000793} & 0 \\ 0 & \underset{(3.6208)}{0.00027} \end{bmatrix}$ $+ \begin{bmatrix} \underset{(4.665)}{0.642} & 0 \\ 0 & \underset{4.1491}{0.704} \end{bmatrix}' \begin{bmatrix} \varepsilon^2_{\pi t-1} & \varepsilon_{\pi t-1}\varepsilon_{gt-1} \\ \varepsilon_{gt-1}\varepsilon_{\pi t-1} & \varepsilon^2_{gt-1} \end{bmatrix} \begin{bmatrix} \underset{(4.665)}{0.642} & 0 \\ 0 & \underset{4.1491}{0.704} \end{bmatrix}$

Notes: the table reports parameter estimates for the Bivariate -BEKK-GARCH(0,1) model. is the inflation rate calculated from the Consumer Price Index. g_t is the growth rate calculated from the GDP. $h_{\pi\pi t}$ is the inflation uncertainty. h_{ggt} is the output growth uncertainty. The numbers in parentheses are the absolute values of the *Z*-statistics.

We calculate Ljung–Box Q statistics at four, eight and 12 lags for the levels, squares, and cross-equation products of the standardized residuals for the estimated bivariate GARCH system. The results, reported in Table 4, show that the time series models for the conditional means and the GARCH (0,1) models for the residual conditional variance–covariance adequately capture the joint distribution of the disturbances.

Table 4: Residual diagnostics

	Inflation Eq (significance level)	**Growth Eq (significance level)**	**Cross Eq (significance level)**
Q(4)	15.398 (0.24)	3.9104 (0.418)	2.0321 (0.73)
Q(8)	17.225 (0.28)	6.2576 (0.618)	15.706 (0.47)
Q(12)	21.79 (0.40)	10.206 (0.598)	18.465 (0.102)
$Q^2(4)$	1.441 (0.837)	8.2066 (.084)	-
$Q^2(8)$	2.3475 (0.968)	15.497 (0.09)	-
$Q^2(12)$	3.4449 (0.992)	16.873 (0.154)	-

Notes: $Q(4)$, $Q(8)$ and $Q(12)$ are the Ljung–Box statistics for fourth-, 8th- and 12th-order serial correlation in the residuals. $Q^2(4)$, $Q^2(8)$ and Q^2 (12) are the Ljung–Box statistics for fourth-, 8th- and 12th-order serial correlation in the squared residuals.

Moreover, we have estimated many other alternative specifications (about 180 equations with VECH, BEKK and CCC specifications) among which, the Bivariate -BEKK-GARCH(0,1) model, as indicated in Table 3, is the most preferred model according to diagnostic tests and Bayesian Information criterion (BIC) (for example, Table 5 compares BIC for 3 alternative model among which, BEKK-GARCH(0,1) attain the minimum value of BIC).

Table 5: Model selection criteria

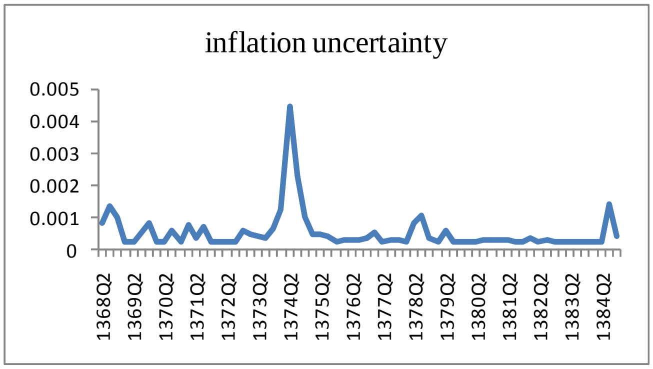
Model	**BIC**
BEKK-GARCH(0,1)	-8.249557
DVECH-GARCH(0,2)	-8.246673
DVECH-GARCH(1,0)	-8.279107

Notes: BIC stands for the Schwartz Bayesian Information Criterion for the *BEKK-GARCH* (0,1) model, *diagonal-vech-GARCH*(0,2) model, and the *Dvech-GARCH*(1,0) model. The bold number indicates the minimum value of the BIC.

We can use the estimated conditional variance of inflation and output equations in our model as proxies of inflation and output growth uncertainties respectively. The estimated nominal and real uncertainties are depicted in Figure 3 below.

In the next step we report the results of Granger-causality tests to provide some statistical evidence on the nature of the relationship between average inflation, output growth, inflation uncertainty, an d output growth uncertainty. Table 6 provides the F statistics of Granger-causality tests using four, eight, and 12 lags, as well as the signs of the sums of the lagged coefficients in the cases that the coefficients are of statistical significance. Panel A considers Granger causality from inflation and output growth to uncertainty about inflation and output growth. We find strong evidence that increased inflation raises inflation uncertainty, confirming the theoretical predictions of Friedman and Ball. Further, the null hypothesis of no Granger causality from output growth to output growth uncertainty is rejected at the 5% level of significance or better for all lags. The association between the two variables is positive, in agreement with the predictions of the theory explained in Section 2, i.e. as output growth rises and an inflationary pressure is created, the monetary authority responds by a monetary contraction which reduces the average rate of inflation and inflation uncertainty and, hence, increases real uncertainty.

a) Inflation uncertainty



b) Economic growth uncertainty

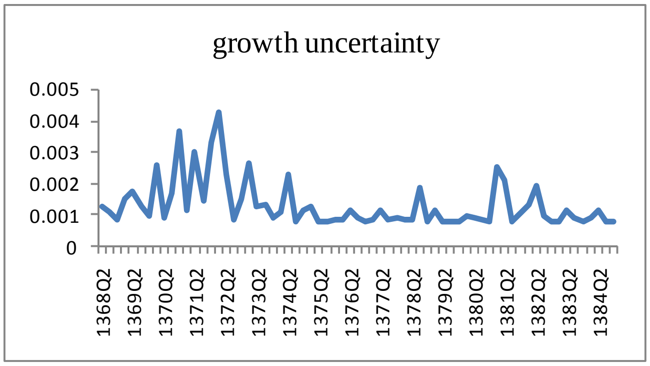


Figure 3: nominal and real uncertainties

So according to results of panel A we can say that increased inflation raises inflation uncertainty, which creates real welfare losses and then leads to monetary tightening and lower inflation and thus also inflation uncertainty. Panel B indicates that there is no strong evidence in favor of the causal effect from inflation uncertainty to inflation and output growth.

Similarly, we cannot reject the null hypothesis of no Granger causality from real uncertainty to output growth in 0.1 levels, except for four lags. In other words we find some support for the idea that more risky output growth is associated with a higher average real growth rate. The sum of the coefficient on lags of output growth uncertainty in output growth equation is positive. We thus provide weak empirical support of Mirman's (1971), Black's (1987) and Blackburn's (1999) hypotheses. We cannot also reject the null hypothesis of no Granger causality from output growth uncertainty to inflation except for 8 lags (in 0.05 level) and 12 lags (in 0.01 level). In other words we cannot reject Deveraux's (1989) and Cukierman and Gerlach's (2003) hypotheses for eight and 12 lags. Thus since the sum of coefficients on real uncertainty in inflation equation is positive, an increase in output growth uncertainty will be associated by an increased inflation. As shown in Table 6, panel C reports the Granger causality between real and nominal uncertainties (first and second columns) and inflation and output growth (third and fourth columns). We find some weak support for Taylor's hypothesis only for 12 lags and not for the other lags. Thus the lack of strong evidence on Taylor's hypothesis, which is necessary to explain the negative causal effect of inflation on output growth uncertainty, can explain the lack of strong evidence on this later effect. We cannot reject other hypotheses represented in panel C, i.e. we have not found strong evidence in favor of bidirectional causal effect between inflation and output growth and also short run Philips curve for Iran.

5- Conclusions

In this paper we use a bivariate GARCH model to simultaneously examine the relationship between uncertainty and average outcomes for inflation and output growth. For this we take seven theoretical arguments to base the empirical work. The first hypothesis was based on the well-known Phillips curve, implying that inflation granger cause output growth. The second one rose by Friedman and Ball, suggest that more inflation increase inflation uncertainty. The third theory proposed a negative effect between inflation uncertainty and growth and was proposed by Friedman. In the Cukierman and Meltzer model, providing the fourth hypothesis, the optimal central bank response to greater inflation noise is to raise the average inflation rate. The Taylor hypothesis proposes that growth uncertainty has a negative impact on inflation uncertainty. Devereux's argument showed that growth uncertainty should increase inflation and, finally, Black proposed a positive connection between growth uncertainty and growth. Only Friedman and Ball's hypothesis was accepted for all the estimations with some weak evidence of Devereux and Black's hypothesis pointing to that real uncertainty have stronger impacts than nominal uncertainties.

We find that, in every estimation, higher inflation significantly increases conditional variance of inflation as argued by Friedman and Ball. This finding suggests the argument of a price stability objective for the monetary authority. Regarding the significant effects of real uncertainties on inflation, there is a strong case for Iran as a dependent-oil country to set up stabilizing mechanisms, insulating the economy from oil revenue volatility. These measures should mitigate output fluctuations arising from to oil boom-bust cycles or unstable domestic policies.

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

Panel A	H_0:$\pi_t \quad h_{\pi t}$ (significance level)	H_0:$\pi_t \quad h_{gt}$ (significance level)	H_0:$g_t \quad h_{gt}$ (significance level)	H_0:$g_t \quad h_{\pi t}$ (significance level)
4 lags	13.6975(+) (9 E-6)	1.59722 (0.1884)	3.14065(+) (0.0215)	1.26742 (0.2942)
8 lags	7.73892(+) (3 E-6)	1.73494 (0.1185)	2.73536(+) (0.00159)	1.0311 (0.4285)
12 lags	3.88974(+) (0.0012)	0.72336 (0.7178)	3.20457(+) (0.0047)	1.56454 (0.1561)
Panel B	H_0: $h_{\pi t} \quad \pi_t$ (significance level)	H_0: $h_{\pi t} \quad g_t$ (significance level)	H_0: $h_{gt} \quad g_t$ (significance level)	H_0: $h_{gt} \quad \pi_t$ (significance level)
4 lags	1.18224 (0.329)	0.42314 (0.7912)	2.10275(+) (0.0931)	1.47309 (0.2232)
8 lags	1.0978 (0.3839)	0.24076 (0.9806)	0.6694 (0.7152)	2.6921(+) (0.01)
12 lags	0.96416 (0.5019)	0.26586 (0.9907)	1.43148 (0.2061)	3.57084(+) (0.0023)
Panel C	H_0:$h_{\pi t} \quad h_{gt}$ (significance level)	H_0:$h_{gt} \quad h_{\pi t}$ (significance level)	H_0: $g_t \quad \pi_t$ (significance level)	H_0: $\pi_t \quad g_t$ (significance level)
4 lags	0.15166 (0.9615)	0.34075 (0.8493)	0.28513 (0.88647)	0.39319 (0.81269)
8 lags	0.40112 (0.9136)	1.19553 (0.3249)	1.8062 (0.10028)	0.33609 (0.94741)
12 lags	0.24416 (0.9936)	4.09356(-) (0.0008)	1.97369 (0.5954)	1.03312 (0.44267)

Notes: $\pi_t \quad h_{\pi t}$: inflation does not Granger-cause inflation uncertainty; $\pi_t \quad h_{gt}$: inflation does not Granger-cause output growth uncertainty; $g_t \quad h_{\pi t}$: output growth does not Granger-cause output growth uncertainty; $g_t \quad h_{gt}$: output growth does not Granger-cause inflation uncertainty.

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 (+) indicates that the sum of the coefficients on lagged growth uncertainty (third and fourth columns) is positive.

In panel C, a (-) indicates the sum of the coefficients on lagged growth uncertainty (second column) is negative.

References

1- Ball, L. (1992). *“Why does high inflation raise inflation uncertainty?,”* Journal of Monetary Economics, 29:371–388.

2- Barro, R. J. & Gordon, D. B. (1983). *“Rules, discretion and reputation in a model of monetary policy,”.* Journal of Monetary Economics, 12:101–121.

3- Barro, R. J. (1996). *“Inflation and growth,”*. Federal Reserve Bank of St. Louis Review, 78(3):450–467.

4- Barro, R.J. (1995), *“Inflation and Economic Growth,”* NBER Working Paper No.w5326.

5- Berndt, E., Hall, B., Hall, R., Hausman, J. (1974). *“Estimation and inference in nonlinear structural models,”*. Annals of Economic and Social Measurement 3, 653–665.

6- Black, F. (1987), *“Business Cycles and Equilibrium,”* Basil Blackwell, New York.

7- Bollerslev, T. & Wooldridge, J. M. (1992). *“Quasi-maximum likelihood estimation and inference in dynamic models with time varying covariances,”*. Econometric Reviews, 11:143–172.

8- Cukierman, A. & Meltzer, A. H. (1986). *“A theory of ambiguity, credibility, and inflation under discretion and asymmetric information,”*. Econometrica, 54:1099–1128.

9- De Gregorio, J. (1993). *“Inflation, taxation and long run growth,”*. Journal of Monetary Economics, 31:271–298.

10- Deveraux, M. (1989). “*A positive theory of inflation and inflation variance,”*. Economic Inquiry, 27:105–116.

11- Dotsey, M. & Sarte, P.-D. (2000). *“Inflation uncertainty and growth in a cash-inadvance economy,”.* Journal of Monetary Economics, 45:631–655.

12- Engle, R. F. & Kroner, K. (1995). “*Multivariate simultaneous GARCH,”*. Econometric Theory, 11:122–150.

13- Fisher, S. (1993). *“The role of macroeconomic factors in growth,”.* Journal Of Monetary Economics, 32:485–512.

14- Friedman, M. (1977). *"Nobel lecture: Inflation and unemployment,"*. The Journal of Political Economy, 85:451–472.

15- Grier, K. B. & Perry, M. J. (2000). *"The effects of real and nominal uncertainty on inflation and output growth: Some GARCH-M evidence,"*. Journal of Applied Econometrics, 15:45–58.

16- Holland S. (1995), *"Inflation and uncertainty: tests for temporal ordering,"* Journal of Money, Credit, and Banking, 27, 827-37.

17- Jones, L. & Manuelli, R. (1995). *"Growth and the effects of inflation,"* Journal of Economic Dynamic and Control, 19:1405–1428.

18- Ramey, G. and V. Ramey (1995), *"Cross-country evidence on the link between volatility and growth,"* American Economic Review 85, 1138-51.

19- Sims, C. (1980). "*Macroeconomics and reality,"*. Econometrica, 48:1–48.

20- Unger, M. and Zilberfard, B., (1993). *"Inflation and its unpredictability- theory and empirical evidence,".* Journal of Money, Credit, and Banking 25, pp. 709-720.