

## Revisiting the Effects of Growth Uncertainty on Inflation in Iran: An Application of GARCH-in-Mean Models

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### Abstract

This paper investigates the relationship between inflation and growth uncertainty in Iran for the period of 1988-2008 by using quarterly data. We employ Generalized Autoregressive Conditional Heteroscedasticity in Mean (GARCH-M) model to estimate time-varying conditional residual variance of growth, as a standard measures of growth uncertainty. The empirical evidence shows that growth uncertainty affects the level of inflation. This result is in line with Feizi Yengjeh (2010), supporting Deveraux (1989) hypothesis.

**Keywords:** Growth Uncertainty, Inflation, GARCH-M models, Iran

**JEL Classification:** C22; E32

### 1. Introduction:

One of the long-standing distinguished topics in macroeconomics has been the interaction between inflation and output growth (see, e.g., Hwang, 2007; Heidari and Bashiri, 2009; Heidari, et al., 2010; and Heidari and Bashiri, 2011, among others). Since Friedman's (1977) Nobel lecture, macroeconomists have identified several potential interactions among inflation, output growth, and their respective uncertainty (see, e.g., Karanasos and Kim, 2005; and Heidari and Bashiri, 2011; among others). Friedman (1977) argues that high inflation produces more uncertainty about future inflation. This uncertainty then lowers economic efficiency and reduces output. Cukierman and Meltzer (1986) and Cukierman (1992) show that, increases in inflation

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uncertainty raise the optimal average inflation rate by increasing the incentive for the policy maker to create inflation surprises. Black (1987) in explaining the relationship between aggregate risk and return, stresses that higher growth uncertainty raises the real growth rate. Logue and Sweeney (1981) point out that inflation uncertainty has a positive impact on output uncertainty. Deveraux (1989) also shows that output growth uncertainty increases inflation.

In the empirical side, there are a lot of empirical investigations of these hypotheses in the literature. Farzinvash and Abbasi (2005); Emami and Salmanpour (2006); Tashkini (2006); Heidari and Montakhab (2008); Heidari and Bashiri (2009); Jafari Samimi and Motameni (2009) and Heidari and Bashiri (2010 and 2011) investigate the relationship between inflation and inflation uncertainty with Iranian data. Their results are in line with others in world wide, supporting Friedman's hypothesis (see, e.g. Perry and Tevfik, 2000; Fountas, 2001; Fountas, et al., 2002; Grier et al., 2004; Apergis, 2004; Kontonikas, 2004; Berument and Nargez Dincer, 2005; Grier and Grier, 2006; Hwang, 2007; Thornton, 2007; Berument, et al, 2009; Jiranyakul and Opiela, 2010; among others ). Moreover, Heidari, et al. (forthcoming) tests Black (1987) hypothesis and finds that a negative relationship between inflation uncertainty and output growth. Their results are in line with others in world wide. (see, e.g. Salai-Martin 1991; Davis and Kanago 1996; Lensink, et al.1999; Judson and Orphanides 1999; Vörk 1999; Wilson and Culver 1999; Grier and Perry 2000; Hayford 2000; Perry and Nas 2000; Caporale and Caporale 2002; Fountas, et al. 2002; Grier, et al. 2004; Apergis 2004; Vale 2005; Grier and Grier 2006; Wilson 2006; Hwang 2007; Fang, et al 2009; among others).

At our best knowledge, there has been only one empirical unpublished study on assessing the relationship between inflation and growth uncertainty with Iranian data. Feizi Yengieh (2010) in his PhD dissertation tried to test the Deveraux (1989) hypothesis, though this study suffers from some technical problems such as autocorrelation in the mean equation of his model. However, this relationship with other countries data has been mixed, at best (see e.g. Grier and Perry, 2000; Grier, et al. (2004); Vale 2005; Fountas and Kraranasos 2006).

This paper reinvestigates the impact of growth uncertainty on inflation with Iranian data. There are some different types of uncertainty in conventional econometrics analysis (see e.g. Wu, et al. 2003, for more discussion). However, we estimate growth uncertainty by using the conditional variance of growth. In this method, the generalized autoregressive conditional heteroscedasticity (GARCH) model is applied to estimate a time-varying conditional residual variance.

The paper contributes to the literature in several respects: First, this paper employs quarterly Iranian data, a country that has experienced significant uncertainty in inflation and economic growth over the last three decades. As far as we know, there has been no serious empirical investigation of the impact of growth uncertainty on inflation for Iranian economy. Second, In order to determine stationarity properties of the series, we use several tests such as Augmented Dickey Fuller (ADF), Philips-Perron (PP), Ng-Perron (NP) and Kwiatkowski et al (KPSS) tests. Third, we examine breaks in the mean of inflation and GDP growth as proxy variables for economic growth. Fourth, we use three alternative GARCH models in dealing with the measurement of growth uncertainty: Bollerslev's (1986) model, Schwert's (1990) model, and Nelson's (1991) exponential GARCH (EGARCH) model. Fifth, by using the last two aforementioned models to measure growth uncertainty, we will be able to examine the possibility of asymmetry in growth uncertainty. Six, we use three different specifications of the growth uncertainty measurement: the conditional variance, the conditional standard deviation, and the natural logarithm of the conditional variance. Our result shows that, there is a significant relationship between growth uncertainty and inflation, supporting the Deveraux (1989) hypothesis.

The rest of the paper is organized as follows: Section 2 introduces the model. Section 3 discusses the data and their properties. In section 4, the estimation results are presented and finally, section 5 concludes.

## 2. The Model

In ordinary least square (OLS) method, the variance of the disturbance term is assumed to be constant over time. However, many economic time series exhibit periods of unusually high volatility

followed by more tranquil periods of low volatility. In such cases, the assumption of homoskedasticity is no longer valid, and it is preferable to examine patterns that allow the variance to depend upon its history. In the case of volatile variance, Engle (1982) suggested that it is better to simultaneously model the mean and the variance of a series.

The general GARCH specification, which is used for growth and time-varying residual variance as a measure of growth uncertainty, is as follows:

$$y_t = \beta_0 + \beta_1 y_{t-1} + \varepsilon_t \quad (1)$$

$$\sigma_{\varepsilon_t}^2 = \omega + \alpha \varepsilon_{t-1}^2 + \beta \sigma_{\varepsilon_{t-1}}^2 \quad (2)$$

Where  $y_t$  is the growth,  $\varepsilon_t$  is the residual,  $\sigma_{\varepsilon_t}^2$  is the conditional variance of the residual term taken as growth uncertainty at time  $t$ . Equation (1) is the mean equation of growth, and equation (2) is a GARCH(1,1) representation of conditional variance.

To investigate the relationship between growth uncertainty and inflation, we use GARCH-in-Mean (GARCH-M) model. In the GARCH-M model, we introduce variance into the mean equation (see, e.g., Engle, et.al 1987), so the mean equation for inflation in the GARCH-M model can be formulated as follows:

$$\pi_t = \theta_0 + \theta_1 \pi_{t-1} + \theta_2 \pi_{t-4} + \theta_3 \pi_{t-6} + \lambda \sigma_{\varepsilon_t}^2 + v_t \quad (3)$$

is the residual.  $v_t$  is the inflation and  $\pi_t$  Where

### 3. Data

In this paper, we use the Consumer Price Index (CPI) and the Gross Domestic Product (GDP) for Iran as proxies for the price level and output, respectively. The data have quarterly frequency and range from 1988:Q2 to 2008:Q1. Inflation is measured by the difference of the log of CPI: (see, e.g. Asteriou, 2006).

$$\pi_t = (\ln cpi_t - \ln cpi_{t-1}) \times 400 \quad (4)$$

Real output growth (here after growth), as proxy for economic growth is measured by the quarterly difference in the log of the GDP:

$$y_t = (\ln GDP_t - \ln GDP_{t-1}) \times 400 \quad (5)$$

Figure 1 shows the inflation and growth rate in the Iranian economy during 1988-2008.

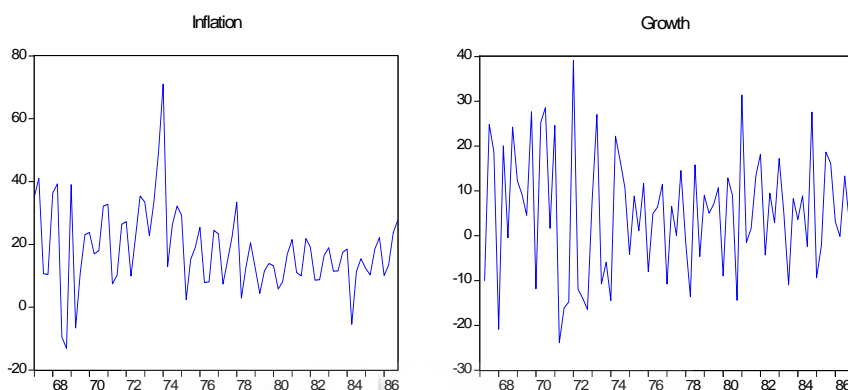


Figure 1: Inflation and Growth Rate in the Iranian Economy

As Figure 1 shows the Iranian economy has experienced volatile inflation and growth rate during last three decades.

The summary statistics for the data is given in Table 1. The large value of the Jargue-Bera statistic for inflation implies a deviation from normality. The value of the Jargue-Bera statistic for growth implies that, the growth is normally distributed.

Table 1: Summary Statistics for Iranian Inflation and Growth

	Inflation	Growth
Mean	18.40236	5.238771
Median	16.92304	5.191709
Maximum	71.05508	39.09165
Minimum	-13.13308	-23.87253
Std. Dev.	13.09108	13.77632
Skewness	0.761437	0.082050
Kurtosis	5.427841	2.396130
Jargua-Bera	27.37852	1.288975
Probability	0.00001	0.524932

In order to determine stationarity properties of the series, we employ several tests such as ADF, PP, NP (2000) and KPSS tests. Table 2 presents the results of these tests. These results reveal that both inflation and growth series are stationary at their levels.

**Table 2: ADF, PP, KPSS and NP test's results for the Iranian inflation and growth**

	Include in test equation	Inflation Statistic	Growth statistics	Critical values 1% level	Critical values 5% level	Critical values 10% level
ADF	Intercept	-3.14200**	-11.1592***	-3.52	-2.90	-2.58
	trend and intercept	-3.21052*	-11.0896***	-4.08	-3.47	-3.16
	none	-0.86052	-9.4627***	-2.59	-1.94	-1.61
PP	Intercept	-6.99511 ***	-11.2777***	-3.51	-2.89	-2.58
	trend and intercept	-7.18589***	-11.2043***	-4.08	-3.46	-3.16
	none	-3.01381***	-9.4461***	-2.59	-1.94	-1.61
KPSS	Intercept	0.40002**	0.1303***	0.73	0.46	0.34
	trend and intercept	0.11011*	0.1306**	0.21	0.14	0.11
Ng-Perron	MZa	-20.9718**	-38.4082***	-23.80	-17.30	-14.20
	MZt	-3.1903**	-4.3780***	-3.42	-2.91	-2.62

Notes:

\* denotes significance at the 10 % level,

\*\* denotes significance at the 10%, 5 % level

\*\*\* denotes significance at the 10%, 5%, 1 % level.

#### 4. Estimates

We find that the best fitting time series model for the Iranian inflation includes 1, 4 and 6 of its lags, and for the growth only one lag:

$$\pi_t = \theta_0 + \theta_1\pi_{t-1} + \theta_2\pi_{t-4} + \theta_3\pi_{t-6} + v_t \quad (6)$$

$$y_t = \beta_0 + \beta_1y_{t-1} + \varepsilon_t \quad (7)$$

In order to find out whether the residuals are serially correlated, we use Breush-Godfrey Serial Correlation Lagrange Multiplier (LM) Test. Table 5 shows that the residuals are not serially correlated.

**Table 5: Breush-Godfrey Serial Correlation LM Test**

	LM test	Probability
<b>Inflation</b>	1.918515	0.3832
<b>Growth</b>	3.072019	0.2152

Moreover to test whether there are any remaining ARCH effects in the residuals, we use the LM test for ARCH in the residuals (see, e.g. Engle 1982). The results of the ARCH-LM test expresses that there is ARCH effect in the residuals.

The Breush-Godfrey Serial Correlation LM Test rejects first through 12 order serial correlation at all standard significant levels. However, the LM tests for ARCH reject the null of no first or eight order conditional heteroskedasticity of the one percent level of significant. As higher order ARCH indicates persistence in the conditional variance, the model is estimated as a GARCH (1,1) process. These results are reported in Tables 6 and 7.

**Table 6: GARCH(1,1) model estimation of inflation**

$\theta$	$\phi_2$	$\phi_1$	$\theta_3$	$\theta_2$	$\theta_1$	$\theta_0$	parameter
-0.1498	0.69058	41.3531	-0.1550	0.3858	0.2492	8.1856	coefficient
0.3026	0.0080	0.0001	0.0141	0.0000	0.0085	0.0000	Prob

**Table 7: GARCH(1,1) model estimation of growth**

$\beta$	$\alpha$	$\omega$	$\beta_1$	$\beta_0$	parameter
0.704569	0.163869	19.08025	-0.275224	6.739984	coefficient
0.0130	0.3085	0.4743	0.0129	0.0000	prob

The results in Tables 6 and 7 reveal that in the mean and variance equation, all coefficients are highly significant.

To investigate the relationship between growth uncertainty and inflation in Iran we report the estimation result of the GARCH-M model in Table 8.

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**Table 8: The Estimation Result of GARCH-M(1,1) Model for Inflation**

$\ln \sigma_{\varepsilon_t}^2$	$\sigma_{\varepsilon_t}$	$\sigma_{\varepsilon_t}^2$	
6.55283 (0.0062)	0.954469 (0.0059)	0.038537 (0.0008)	$\lambda$
28.9665 (0.0011)	31.10197 (0.0005)	32.65707 (0.0001)	$\phi_1$
0.70579 (0.0033)	0.690085 (0.0030)	0.871078 (0.0072)	$\phi_2$
-0.028025 (0.7952)	-0.045620 (0.6363)	-0.108462 (0.2129)	$\theta$

The coefficient of conditional variance in the mean equation ( $\lambda$ ) is positive and significant, which means that growth rate uncertainty affects inflation positively.

#### 4.1 The TGARCH Model:

In this section, we investigate whether the magnitude of the effect of positive and negative growth innovations on uncertainty is the same or not. To do this, we use TGARCH model. Considering the role of asymmetry, we can define our TGARCH model as follows:

$$y_t = \beta_0 + \beta_1 y_{t-1} + \varepsilon_t \quad (8)$$

$$\sigma_{\varepsilon_t}^2 = \omega + \alpha \varepsilon_{t-1}^2 + \gamma \varepsilon_{t-1}^2 D + \beta \sigma_{\varepsilon_{t-1}}^2 \quad (9)$$

As Caporale and Caporale (2002) explains, in this model, good news ( $\varepsilon_{t-1} \geq 0$ ) and bad news ( $\varepsilon_{t-1} < 0$ ) have different effects on the conditional variance. This model allows negative growth shocks, ( $\varepsilon_{t-1} < 0$ ) to have a different effect on growth uncertainty than positive ones. Specially, negative shocks have total impact of  $\alpha + \gamma$ , whereas positive shocks have an effect equal to  $\alpha$ . If  $\gamma$  is statistically different from zero, these shocks have an asymmetric effect on growth uncertainty. The estimation result of the above TGARCH model is presented in Table 9:



**Table 9: The Estimation Result of TGARCH(1,1) model for growth uncertainty**

$\beta$	$\gamma$	$\alpha$	$\omega$	$\beta_1$	$\beta_0$	parameters
0.75587	-0.1488	0.22594	15.5499	-0.3062	7.12163	coefficients
0.0051	0.6372	0.4532	0.5143	0.0172	0.0000	Prob

As can be seen from Table 9, in the estimated model,  $\gamma$  is negative and insignificant which means that the news impact is symmetric.

We can test the asymmetry in the news impact by testing the null hypothesis that  $\gamma$  is equal to zero against the alternative hypothesis that it is different from zero. If we reject the null, the news impact is asymmetric. With this result in hand, we can reject the null that the news impact is asymmetric.

**Table 10: Wald Test Result for the Asymmetry**

F-statistic	Probability
0.222463	0/6387

We need to choose the form in which the time-varying variance enters the specification of the mean equation to determine the measure of uncertainty. Caporale and Mckiernan (1996) found that the logarithm of the conditional variance works better in their estimation of the time-varying risk premium. However, as noted by Pagan and Hong (1991), the use of  $\ln \sigma_t^2$  is possibly unsatisfactory. On the other hand, one can use the conditional standard deviation as a regressor in the conditional mean (see, e.g., Henry and Olekalns, 2002). Therefore we employ all three specifications for the time-varying variance.

To investigate the relationship between growth uncertainty and inflation, we define our TGARCH-M model as follows:

$$\pi_t = \theta_0 + \theta_1 \pi_{t-1} + \theta_2 \pi_{t-4} + \theta_3 \pi_{t-6} + \lambda \sigma_{T\bar{\pi}}^2 + v_t \quad (10)$$

$$\sigma_{v_t}^2 = \phi_1 + \phi_2 v_{t-1}^2 + \theta \sigma_{v_{t-1}}^2 \quad (11)$$

The estimation results of our TGARCH-M model with these three different alternative of growth uncertainty measurement are reported in Table 11.

As can be seen from Table 11, the coefficient of conditional variance in the mean equation is positive and significant, which means that growth uncertainty affects on inflation.

Table 11: The Estimation Results of TGARCH-M(1,1) model for the mean equation

$\ln \sigma_{T\varepsilon_t}^2$	$\sigma_{T\varepsilon_t}$	$\sigma_{T\varepsilon_t}^2$	
6.984214 (0.0001)	1.018945 (0.0004)	0/032836 (0.0021)	$\lambda$
20.76132 (0.0185)	23.48779 (0.0079)	26.20130 (0.0035)	$\phi_1$
0.929167 (0.0062)	0.834775 (0.0050)	0.746913 (0.0041)	$\phi_2$
-0.003834 (0.9582)	-0.003782 (0.9675)	-0.0039 (0.9733)	$\theta$

#### 4.2 The EGARCH Model:

An extended version of GARCH models which proposed by Nelson (1991), is EGARCH. As Berument, et al. (2002) expresses, the EGARCH models are more advantageous than GARCH models to model growth uncertainty for the following reasons: First, it allows for the asymmetry in the responsiveness of growth uncertainty to the sign of shocks to growth. Second, unlike GARCH specification, the EGARCH model, specified in logarithms, does not impose the non-negativity constraints on parameters. Finally, modeling growth and its uncertainty in logarithms hampers the effects of outliers on the estimation results. The best EGARCH specification for the Iranian growth can be defined as follows:

$$y_t = \beta_0 + \beta_1 y_{t-1} + \varepsilon_t \quad (12)$$

$$\log(\sigma_{E\varepsilon_t}^2) = \omega + \alpha \left| \frac{\varepsilon_{t-1}}{\sigma_{E\varepsilon_{t-1}}} \right| + \gamma \frac{\varepsilon_{t-1}}{\sigma_{E\varepsilon_{t-1}}} + \theta \log(\sigma_{E\varepsilon_{t-1}}^2) \quad (13)$$

We report the results of above model in Table 12. Following Wilson (2006), in this table, positive value for the  $\alpha$  means that a deviation of  $\left| \frac{\varepsilon_{t-i}}{\sigma_{t-j}} \right|$  from its expected value causes growth uncertainty to rise. Positive value for the  $\gamma$  means that the growth uncertainty will rise more in response to positive growth shocks ( $\varepsilon_{t-i} > 0$ ) than to negative shocks ( $\varepsilon_{t-i} < 0$ ). If  $\gamma = 0$ , then a positive shock to growth has the same effect on uncertainty as a negative shock of the same magnitude.

**Table 12: The Estimation Results of EGARCH model for the growth uncertainty**

$\theta$	$\gamma$	$\alpha$	$\omega$	$\beta_1$	$\beta_0$	parameters
-0.53239	-0.28555	0.6389	7.38142	-0.30579	7.3049	coefficients
0.0428	0.0917	0.0611	0.0000	0.0006	0.0000	prob

As can be seen from Table 12, in the estimated model,  $\gamma$  is negative and insignificant which means that the news impact has symmetric effect, and positive shock to growth has the same effect on uncertainty as a negative shock of the same magnitude.

As the effect of growth on growth uncertainty is symmetric, we again estimate this equation without the term  $\left| \frac{\varepsilon_{t-i}}{\sigma_{t-j}} \right|$ . Table 13 reports the result of EGARCH model estimation for this new specification.

**Table 13: The Estimation Result of EGARCH model for the growth uncertainty**

$\theta$	$\alpha$	$\omega$	$\beta_1$	$\beta_0$	parameters
0.873053	0.314226	0.385612	-0.294131	6.756727	coefficients
0.0000	0.2665	0.6224	0.0150	0.0000	prob

To investigate the relationship between growth uncertainty and inflation, we use EGARCH-M model as follows:

$$\pi_t = \theta_0 + \theta_1 \pi_{t-1} + \theta_2 \pi_{t-4} + \theta_3 \pi_{t-6} + \lambda \sigma_{Tst}^2 + v_t \quad (15)$$

$$\sigma_{v_t}^2 = \phi_1 + \phi_2 v_{t-1}^2 + \theta \sigma_{v_{t-1}}^2 \quad (16)$$

We report the estimation result of this model in Table 14.

**Table 14: The Estimation Result of EGARCH-M model of inflation**

$\ln \sigma_{E\varepsilon_t}^2$	$\sigma_{E\varepsilon_t}$	$\sigma_{E\varepsilon_t}^2$	
6.841338 (0.0028)	1.050709 (0.0019)	0.036871 (0.0019)	$\lambda$
27.12200 (0.0034)	28.97784 (0.0015)	29.80108 (0.0007)	$\phi_1$
0.722062 (0.0038)	0.706762 (0.0032)	0.697289 (0.0030)	$\phi_2$
-0.018782 (0.8759)	-0.034299 (0.7530)	-0.040388 (0.6986)	$\theta$

The coefficient of conditional variance in the mean equation ( $\lambda$ ) is positive and significant, which means that growth uncertainty affects on inflation.

### 5. Conclusion:

In this paper, we have investigated empirically the relationship between growth uncertainty and inflation in Iran for the period of 1988-2008 by using quarterly data and applying GARCH-M model. We estimate growth uncertainty by assuming that uncertainty is due to shocks to the growth process, and therefore measures growth uncertainty by using the conditional variance of growth. In this method, the GARCH model is applied to estimate a time-varying conditional residual variance. The result shows that growth uncertainty affects inflation. This result is in line with those of Feizi-Yengjeh (2010), supporting Deveraux (1989) hypothesis. Our results also show that negative growth shocks have the same effect on growth uncertainty, in comparing with positive ones. Moreover, the results are robust to the form of time-varying variance that enters to the mean equation.

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