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Relationship between Inflation and Inflation Uncertainty in Iran: An Application of SETAR-GARCH Model

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Abstract

The purpose of this paper is to investigate the relationship between the inflation and inflation uncertainty in Iran. Using mixed models of self-exciting threshold autoregressive (SETAR) and generalized autoregressive conditional heteroskedasticity (GARCH), the inflation behaviors are examined for the period 1990M05-2013M10. This approach allows testing the hypotheses of Friedman-Ball, Pourgerami-Maskus, Cukierman-Meltzer, and Holland during different inflationary regimes. The results indicate that an increase in Iran's inflation leads to higher inflation uncertainty, as predicted by Friedman-Ball Hypothesis, while the other three hypotheses are not confirmed. Positive unidirectional causality from inflation to uncertainty seems to be significant only in periods of relatively higher inflation, but not in periods of low inflation. The finding is important because it confirms the existence of regime-dependent effect of inflation on public's expectations about future inflation; that, in trend, it reduces economic activity and misallocates resources. This is a new insight about asymmetric behaviour of inflation in Iran that has noteworthy implications for policy-makers, especially for price stabilizing and inflation targeting.

Keywords: *Inflation uncertainty, Nonlinearity, Self-exciting threshold autoregressive, Iran*
JEL Classifications: *C22, E31.*

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1. Introduction

Over the last two decades, inflation was a major problem of the economy of Iran. Iran experienced higher inflation with more fluctuations in the 1990s. The inflation trend, conducting anti-inflation policies since 2000, was downward and at the same time relatively stable. But after five years, the inflation has begun to rise, especially from the late 2011. It seems that a new period of abnormally increasing prices with more fluctuations has started.

In this paper we investigate Iran inflation behavior by an autoregressive process. The simplest type of autoregressive process is linear autoregressive. This simple process, cannot provide a sufficient level of fitting to variables and especially to inflation behavior for two reasons. First, economic phenomena and variables are too often complicated to be explained by linear equations. Second, these variables and especially inflation are in a permanent interaction with economic agents' (consumers, producers and government) behavior. Low and high inflations have different impacts on the behavior of economic agents, thus triggering different reactions. These different reactions result in different feedback on inflation. For example, high inflation destabilizes economy, with the probability of being sticky, while low inflation does not soar high. Governments react to inflation level differently. This reaction can be very intense and rapid to high inflation, while low inflation usually faces no significant reaction and continues slowly.

The main purpose of this paper is to investigate and compare the relationship between inflation and inflation uncertainty in the two regimes of low and high inflation. The paper investigates Iran inflation behavior by mixed models of self-exciting threshold autoregressive (SETAR) and generalized autoregressive conditional heteroskedasticity (GARCH). It examines nonlinearity in the behavior of inflation rate using the monthly inflation rate for the period 1990M05-2013M10. It provides new insights into the asymmetric behavior of inflation in Iran, and has important implications for policy-makers and inflation targets.

The remainder of this paper is organized as follows: Section 2 describes theoretical and empirical studies. Section 3 provides a brief description of SETAR-GARCH model. Section 4 discusses the empirical results and analyzes inflation behavior. Finally, Section 5 presents a summary of the main findings.

2. Literature Review

In general, there are four hypotheses about the relationship between inflation and uncertainty. At the first time, Okun (1971) provided some evidence about the relationship between inflation and its fluctuations. He argued that there is a positive relationship between inflation and inflation variability since monetary policy becomes more unpredictable during the periods of high inflation. Then Friedman (1977) and Ball (1992) demonstrated that high inflation accommodates political pressure to reduce it, while some policymakers may be reluctant to take disinflation policy because they fear the recessionary effects. So, when the current inflation rises, the public faces increasing uncertainty about future inflation. In other words, the response of policymaker in the next period is not known. Hence higher inflation results in higher uncertainty about future money supply growth and subsequently, about future inflation which is called *Friedman-Ball Hypothesis*.

Ball (1992) argues that, in high-inflation periods, prediction of future monetary policy is more difficult for the public. But Pourgerami and Maskus (1987) believe that agents (consumers and producers) may invest more resources in forecasting inflation, thus an increase in inflation is associated with lower average uncertainty about future inflation. Ungar and Zilberfarb (1993) provide a formal analysis of this effect. This argument implies a negative causal effect from inflation to inflation uncertainty which is known as *Pourgerami-Maskus Hypothesis.*

Reversing the causation link of the *Friedman-Ball* and *Pourgerami-Maskus Hypotheses*, Cukierman and Meltzer (1986) show that, during the periods of higher uncertainty, monetary authority has more incentive to stimulate output by surprising monetary policy, and in turn they follow more discretionary policy instead of the commitment mechanism. It means that higher inflation uncertainty will raise the average inflation rate. This positive causal effect of inflation uncertainty on inflation is called *Cukierman-Meltzer Hypothesis*.

Holland (1995), against the above hypothesis, suggests a different idea based on the stabilization motive of monetary authority. He asserts that the stabilization tendency of central bank depends on the welfare cost of inflation uncertainty. When higher inflation results in an increase in inflation uncertainty, the welfare cost rises due to inflation uncertainty. Therefore, the monetary authority reacts by contracting money supply growth for eliminating inflation uncertainty and the associated negative welfare effects. Higher inflation uncertainty will decrease the average inflation rate. This negative causal effect of inflation uncertainty on inflation is called *Holland Hypothesis.* Since the negative causal effect is an evidence of a stabilizing central bank, it is also known as *Stabilizing Fed Hypothesis*.

However, the relationship between inflation and inflation uncertainty is considered by many empirical studies such as Evans (1991), Baillie et al. (1996), Grier and Perry (1998, 2000), Kontonikas (2004), Daal et al. (2005), Conrad and Karanasos (2005), Berument and Dincer (2005), Wilson (2006), Fountas and Karanasos (2007), Thorton (2007), Özdemir and Fisunoğlu (2008), Fountas (2010), Balcilar et al. (2011), Chang (2012), Hartmann and Herwartz (2012), Karahan (2012), Neanidis and Savva (2013), Daniela et al. (2014), Nasr et al. (2015) and Buth et al. (2015).

These studies often use the autoregressive type processes, while GARCH techniques are used to generate the conditional variances of inflation as a measure of inflation uncertainty. Finally, conditional variance series is employed to perform Granger-causality tests. The summary of their results is shown in Table 1.

The majority of studies concluded that there is a positive bidirectional causality relationship between inflation and inflation uncertainty. Therefore, they support both the *Friedman-Ball Hypothesis* and *Cukierman-Meltzer Hypothesis*. Furthermore, there are pieces of evidence in favor of the nonlinear relationship between inflation and uncertainty. For example, Ungar and Zilberfarb (1993) emphasized that this relationship is significant only in the periods of high inflation, and so a threshold effect may exist. Recently, Chang (2012) indicates that inflation has a negative effect on uncertainty during periods of high-inflation volatility, while its effect is insignificant during periods of low-inflation volatility.

According to the theories of Ball (1992) and Cukierman and Meltzer (1986), inflation uncertainty is the variance of the unpredictable component of an inflation forecast which is called the conditional variance of inflation. To quantify inflation uncertainty, a variety of measures are employed by the very last studies, but none of them compute the inflation uncertainty correctly. For example, Kline (1977) employed the moving standard deviation of the inflation rate. Also Ungar and Zilberfarb (1993) used the mean squared error of inflation forecasts.

However, Baillie et al. (1996) and Berument and Dincer (2005) argued that these estimates have bias, and would not be the reliable measures. In addition, they measured inflation variability, not uncertainty. The development of GARCH techniques by Engle (1982) and Bollerslev (1986) allows that inflation uncertainty can be properly measured by the conditional variance of the inflation. For this reason, as it is evident in Table 1, all of the recent studies used GARCH techniques to generate a suitable measure of inflation uncertainty.

Table 1: Empirical Studies

Study	Method	Country
Friedman-Ball Hypothesis (inflation $\overset{+}{\rightarrow}$ inflation uncertainty)		
Evans (1991)	GARCH	US
Ungar and Zilberfarb (1993)	LS/WLS	Israel (in high-inflation periods)
Baillie et al. (1996)	GARCH	Argentina, Brazil, Israel
Grier and Perry (1998)	GARCH	Canada, France, Germany, Italy, Japan, UK, US
Kontonikas (2004)	GARCH-M	UK
Berument and Dincer (2005)	GARCH	Canada, France, Germany, Italy, Japan, UK, US
Daal et al. (2005)	PGARCH	Argentina, Bahrain, Canada, Colombia, Egypt, France, India, Indonesia, Italy, Japan, Korea, Mexico, Morocco, Pakistan, Sri Lanka, Thailand, Turkey, UK, US, Venezuela
Conrad and Karanasos (2005a)	FIGARCH	Japan, UK, US
Conrad and Karanasos (2005b)	FIGARCH	Belgium, Finland, France, Germany, Italy, Netherlands, Portugal, Spain, Sweden, UK
Fountas and Karanasos (2007)	GARCH	Canada, France, Germany, Italy, Japan, UK, US
Thorton (2007)	GARCH	Colombia, Hungary, Jordan, India, Indonesia, Israel, Korea, Malaysia, Mexico, South Africa, Thailand, Turkey
Özdemir and Fisunoğlu (2008)	GARCH	Jordan, Philippines, Turkey
Fountas (2010)	GARCH-M	Australia, Germany, Italy, New Zealand, Sweden, US
Jiranyakul and Opiela (2010)	EGARCH	Indonesia, Malaysia, Philippines, Singapore, Thailand
Balcilar et al. (2011),	GARCH	Japan, UK, US
Karahan (2012)	GARCH	Turkey
Hartmann and Herwartz (2012)	GARCH	22 developed economies
Daniela et al. (2014)	GARCH-M	Czech Republic, Poland, Hungary, Romania, Turkey
Nasr et al. (2015)	GARCH	South Africa
Buth et al. (2015)	GARCH	Cambodia, Lao PDR, Vietnam
Pourgerami-Maskus Hypothesis (inflation $\overset{-}{\rightarrow}$ inflation uncertainty)		
Ungar and Zilberfarb (1993)	LS/WLS	Israel (in high-inflation periods)

Study	Method	Country
Fountas (2010)	GARCH-M	Finland, France, Germany (1924-2003), Ireland, Netherlands
Cukierman-Meltzer Hypothesis (inflation uncertainty $\overset{+}{\rightarrow}$ inflation)		
Baillie et al. (1996)	GARCH	Argentina, Brazil, Israel
Grier and Perry (1998)	GARCH	Japan, France
Grier and Perry (2000)	GARCH-M	US
Berument and Dincer (2005)	GARCH	Canada, France, UK, US
Daal et al. (2005)	PGARCH	Bahrain, Egypt, Indonesia, Italy, Germany, UK
Conrad and Karanasos (2005a)	FIGARCH	Japan, UK
Conrad and Karanasos (2005b)	FIGARCH	France, Spain, Netherlands
Wilson (2006)	EGARCH-M	Japan
Thorton (2007)	GARCH	Hungary, Indonesia, Korea
Fountas and Karanasos (2007)	GARCH	Germany, Italy, Japan
Fountas (2010)	GARCH-M	In most 22 industrial countries
Jiranyakul and Opiela (2010)	EGARCH	Indonesia, Malaysia, Philippines, Singapore, Thailand
Balcilar et al. (2011),	GARCH	Japan, UK, US
Karahan (2012)	GARCH	Turkey
Neanidis and Savva (2013)	EGARCH-M	Germany, Japan, UK, US, Canada, Italy, France
Daniela et al. (2014)	GARCH-M	Czech Republic, Romania, Turkey
Buth et al. (2015)	GARCH	Lao PDR
Holland Hypothesis (inflation uncertainty $\overset{-}{\rightarrow}$ inflation)		
Grier and Perry (1998)	GARCH	Germany, UK, US
Berument and Dincer (2005)	GARCH	Japan
Conrad and Karanasos (2005a)	FIGARCH	Japan and UK
Conrad and Karanasos (2005b)	FIGARCH	Sweden
Daal et al. (2005)	PGARCH	India, Colombia, Venezuela
Fountas and Karanasos (2007)	GARCH	Canada
Thorton (2007)	GARCH	Colombia, Israel, Mexico, Turkey
Chang (2012)	GARCH-M	US (during periods of high inflation volatility)
None of the above *Hypotheses*		
Baillie et al. (1996)	GARCH	Canada, France, Germany, Italy, Japan, US
Daal et al. (2005)	PGARCH	Peru
Fountas (2010)	GARCH-M	Switzerland
Chang (2012)	GARCH-M	US (during periods of low inflation volatility)

Sources: Authors' findings.

3. The Model

The self-exciting autoregressive model was introduced to the literature of econometrics by Tong (1978) and then widely applied by Tsay (1989, 1998), Chan (1993), and Hansen (1996, 1997, 1999, 2000). This model is denoted in a general form as:

$$y_t = Y_t'\varphi_1 . I[y_{t-d} - c < 0] + Y_t'\varphi_2 . (1 - I[y_{t-d} - c < 0]) + \varepsilon_t, \quad (1)$$

where $Y_t = (1, y_{t-1}, \dots, y_{t-p})'$, $\varphi_j = (\varphi_{j0}, \varphi_{j1}, \dots, \varphi_{jp})'$, p is the lag length, j is the regime, and y_{t-i} and φ_{ji} are the lag variable and coefficient, respectively. $I[y_{t-d} - c < 0]$ is an indicator function in which y_{t-d} and c are the threshold variable and parameter, respectively. Based on the φ_1 and φ_2, the variable behavior is described in the two regimes of low and high inflation levels. In addition, the mean lag (MNL) of regime $j(= 1, 2)$ is calculated as: $MNL_j = (\sum_{i=1}^{p} i . \varphi_{ji})/(\sum_{i=1}^{p} \varphi_{ji})$ that can be used to examine the persistence of regime.

If ε_t is conditionally heteroscedastic, the error term can be defined as $\varepsilon_t(d, c) = h_t(d, c)^{0.5}\epsilon_t$ where ϵ is independent and identically distributed with zero mean and unit variance. Then, based on the Engle (1982) and Bollerslev (1986), generalized autoregressive conditionally heteroscedastic (GARCH) model denoted in a general form as:

$$h_t(d, c) = H_t\theta + E_t\vartheta \quad (2)$$

where $H_t = [h_{t-1}(d, c), \dots, h_{t-s}(d, c)]$, $\theta = (\theta_1, \dots, \theta_s)'$, $E_t = (1, \varepsilon_{t-1}^2(d, c), \dots, \varepsilon_{t-q}^2(d, c))$, and $\vartheta = (\vartheta_0, \vartheta_1, \dots, \vartheta_q)'$ in which the orders s and q are the lag length of conditional variances and squared error terms, respectively.

To estimate, if the delay or threshold lag (d) and threshold parameter (c) are estimated consistently, then the coefficients can be estimated consistently by the least squares method. According to Chan (1993), SETAR model is estimated drawing upon the given values of delay lag and threshold parameters, and then the best fitting is selected; in other words:

$$(\hat{d},\hat{c}) = \underset{d\in \mathrm{D}\;\; c\in C}{argmin}\;\hat{\varepsilon}(d,c)'\hat{\varepsilon}(d,c), \tag{3}$$

where $D = \{1,2,\dots,p\}$. By minimizing the sum of squared residuals, a consistent estimation of threshold parameter is reached, and the super consistent estimation of delay lag is resulted since d is picked among the range of discrete numbers. Then the coefficients vector are determined as $\hat{\varphi}(\hat{d},\hat{c}) = (\sum_{t=1}^{T} Y_t(\hat{d},\hat{c})Y_t'(\hat{d},\hat{c}))^{-1}\sum_{t=1}^{T} Y_t(\hat{d},\hat{c})\,y_t$ and the error terms variance is estimated as $\hat{\sigma}_\varepsilon = \hat{\varepsilon}(\hat{d},\hat{c})'\hat{\varepsilon}(\hat{d},\hat{c})/T$.

Considering the null hypothesis $H_0\colon \varphi_1 = \varphi_2$, the existence of threshold is tested by $F = [\tilde{\varepsilon}'\tilde{\varepsilon} - \hat{\varepsilon}(\hat{d},\hat{c})'\hat{\varepsilon}(\hat{d},\hat{c})]/\hat{\sigma}_\varepsilon$ where $\tilde{\varepsilon}$ is the residual of linear autoregressive. Hansen (1996) describes that F distribution is non-standard and depends on the moments of sample, and so the critical values cannot be tabulated. So, following the suggestion of Hansen (1996, 1997), the bootstrap procedure should be used. Based on the sample residuals distribution, a new sample under the null hypothesis is produced. With the new sample, the coefficients are estimated (under the null and alternative hypotheses) and the simulated F statistic is obtained. Then the process is repeated and the *p-value* based on the number of simulated F statistic that exceeds actual estimation of F is calculated. This method can be used for testing the existence of multiple thresholds.

Hansen (1997, 1999), considering the null hypothesis $H_0\colon c = c_0$, suggests the likelihood ratio statistic, $LR(c_0) = [\hat{\varepsilon}(\hat{d},c_0)'\hat{\varepsilon}(\hat{d},c_0) - \hat{\varepsilon}(\hat{d},\hat{c})'\hat{\varepsilon}(\hat{d},\hat{c})]/\hat{\sigma}_\varepsilon$, which can be used for the construction of confidence interval of the threshold. Hansen shows that this statistic converges in distribution to the random variable ξ which its reverse distribution is $c(\alpha) = -2\,log(1-\sqrt{1-\alpha})$. Therefore, the confidence interval $(1-\alpha)$ percent will be constructed for the threshold by $LR(c_0) \le c(\alpha)$. It should be noted that the hypothesis $H_0\colon \varphi_1 = \varphi_2$ is different from the hypothesis $H_0\colon c = c_0$. The F statistic is for testing the existence of threshold, while the $LR(c_0)$ statistic is used for constructing the confidence interval of the present threshold.

Finally, the residual of Eq. (1) is defined as $\hat{\varepsilon}_t(\hat{d},\hat{c}) = \hat{h}_t(\hat{d},\hat{c})^{0.5}\hat{\epsilon}_t$ and then the conditional variance is estimated as $\hat{h}_t(\hat{d},\hat{c}) = \hat{H}_t'\theta + \hat{\mathrm{E}}_t'\vartheta$. The estimated unconditional variances series is used as a measure of volatility (or uncertainty) in the low and high regimes, and also it is used for testing Granger causality between variable and its uncertainty.

4. The Inflation Behavior Results

The data for consumer price index (CPI) is obtained from the Central Bank of Iran[1]. According to Augmented Dickey and Fuller (1979), Elliott, Rothenberg and Stock (1996), and Phillips and Perron (1988) tests, the stationarity of monthly inflation rate is confirmed. The results are shown in Table 2.

Table 2: Unit Root Tests

	ADF			ERS (DF-GLS)		PP		
	Non	Constant	Trend	Constant	Trend	Non	Constant	Trend
t-Stat	-6.2187	-10.4406	-10.4531	-4.2932	-6.7548	-5.8467	-10.3810	-10.3917
p-value	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)

Source: Research findings

The lag length 12 is determined based on the maximum likelihood method and Akaike Information Criterion. Then the delay lag and threshold parameters are determined by minimizing the sum of squared residuals of nonlinear model, Eq. (3). The results show that SETAR model is estimated consistently with $\hat{d} = 1$ and $\hat{c} = 2.60$ (Table 3).

Table 3: Selection of Threshold Variable

(d, c)	$\sigma_{SETAR}^2/\sigma_{LAR}^2$	(d, c)	$\sigma_{SETAR}^2/\sigma_{LAR}^2$	(d, c)	$\sigma_{SETAR}^2/\sigma_{LAR}^2$
(1, 2.60)	0.7958	(5, 2.06)	0.8233	(9, 2.51)	0.8616
(2, 1.80)	0.8803	(6, 2.15)	0.8938	(10, 2.68)	0.9071
(3, 1.76)	0.8812	(7, 1.24)	0.8865	(11, 1.33)	0.8482
(4, 2.25)	0.8832	(8, 2.48)	0.8649	(12, 2.44)	0.8958

Source: Research findings

1. There are two ways to consider seasonality in time series. The first way, as the present study, assumes that seasonal variation appears in the lag structure, and so the regime switching models can consider it correctly. The second way is to use seasonality adjusted data which is usually less satisfactory and leads to unfortunate consequences (see Davidson and Mackinnon, 2004. p. 570; Franses and van Dijk, 2000, p. 58, for details).

In the next step, the existence of first threshold is strongly confirmed by 20000 bootstrap replications of F-statistic of Hansen (1996, 1997). But F-statistic of the second threshold is not significant, and the existence of second threshold is not confirmed. Thus the model is estimated with single threshold 2.60 per cent. The adjusted R-squared of the nonlinear model is almost 40 percent and it is considerably larger than 28 per cent of the linear model (Table 4).

Ljung and Box (1978) and Eitrheim and Teräsvirta (1996) methods are used to test autocorrelation. Also heteroskedasticity is tested by McLeod and Li (1983) method. The results shown that there is no autocorrelation, but the presence of heteroskedasticity is confirmed. Therefore, the standard errors and confidence intervals are corrected by heteroskedasticity-consistent covariance matrix estimator (see White, 1980; MacKinnon and White, 1985; West, 1997, for details).

The threshold of inflation is 2.60 percent with the confidence intervals (2.41% 2.70%). The first and second regimes have 228 and 42 observations, respectively. There are enough observations in both sides of the threshold value, and thereby, the estimated parameters are credible. In the first regime, the inflation rate is mainly determined by inflation rate of the past month and the same month last year (1^{st} and 12^{th}). But in the second regime, the inflation rate is significantly and positively related to the 1^{st}, 7^{th}, 10^{th} and 11^{th} lags, and negatively to 8^{th} and 9^{th} lags. Since the mean lag (MNL) of parameters in the second regime is greater than the first regime, it is expected that inflation higher than 2.5 per cent would be more persistent.

On the other hand, the error variance of the second regime is 2.31, which is significantly larger than the first regime (0.80)[1]. The larger variance of the second regime indicates more fluctuations in higher inflation, and so the process of rising prices is associated with deflationary and inflationary extremes. Therefore, the changes in inflation are evidently more rapid with high fluctuations when compared to the first regime. This is evident in Fig. 2 and 3, which will be analyzed below.

1. F-test for the equality of variances is 2.88, which is significant at 1 percent level.

Table 4: SETAR-GARCH Model

	Low-inflation regime **($INF_{t-1} \leq 2.60$)**			***high-inflation regime*** **($INF_{t-1} \geq 2.60$)**		
	Coefficient	LS S.E.	HCC S.E.	Coefficient	LS S.E.	HCC S.E.
Constant	0.3090	0.1980	0.1702	-1.6508	0.6474	0.7875
INF_{t-1}	0.4170	0.0917	0.0820	0.4490	0.1805	0.2778
INF_{t-2}	0.0413	0.0644	0.0641	-0.0521	0.1676	0.2306
INF_{t-3}	0.0825	0.0646	0.0602	0.0290	0.1716	0.2969
INF_{t-4}	0.0271	0.0649	0.0520	0.0975	0.1555	0.2805
INF_{t-5}	-0.0838	0.0646	0.0577	0.0653	0.1528	0.1931
INF_{t-6}	0.0576	0.0646	0.0500	0.0586	0.1797	0.2621
INF_{t-7}	-0.1105	0.0647	0.0468	0.8924	0.1916	0.1985
INF_{t-8}	0.1311	0.0653	0.0541	-0.3774	0.1731	0.2807
INF_{t-9}	0.0049	0.0655	0.0596	-0.3829	0.1965	0.2434
INF_{t-10}	-0.0721	0.0662	0.0584	0.2612	0.1493	0.2080
INF_{t-11}	0.1276	0.0703	0.0669	0.6110	0.1303	0.2199
INF_{t-12}	0.2405	0.0667	0.0721	0.1128	0.1149	0.2169
MNL	5.4102			6.2617		
σ_ε^2	0.8014			2.3097		
Obs	228			42		
$F_{first\ threshold}$=69.2923 (0.0000)			$2.41 \leq c \leq 2.70$		$F_{second\ threshold}$=14.2416 (0.5450)	
$LB(1)$=0.0226			$ET(1)$=0.0531		McL=44.8408	
R^2_{LAR}= 0.2815			R^2_{SETAR}= 0.3978		LM_{SETAR}=0.0964 (0.0082)	
h_t= 0.5676 + 0.5490 ε_{t-1}^2 (0.0934) (0.1652)			R^2_{GARCH}= 0.2866		LM_{GARCH}=0.5090 (0.4762)	

Notes: F statistics for the first and second threshold tests are estimated with 20000 bootstrap replications.
R^2_{LAR}, R^2_{SETAR} and R^2_{GARCH} are the adjusted R-squared of linear autoregressive, SETAR and GARCH models, respectively.
LB and *ET* statistics are Ljung-Box and Eitrheim-Teräsvirta tests for autocorrelation, respectively. *McL* statistic is McLeod-Li test for heteroskedasticity. *LM* statistics is Lagrange Multiplier test for ARCH effects.

Source: Research findings

Before modeling inflation volatility, the Lagrange Multiplier (LM) test is performed to examine whether the inflation has ARCH effects. The result shows that the null hypothesis of no ARCH effects is rejected for the SETAR model. So, the inflation volatility is modeled with a GARCH specification. Based on the Akaike Information Criterion and not rejecting the null hypothesis of no ARCH effects, the lag lengths of squared error terms and conditional variances are selected as one and zero, respectively. The conditional variances (CV) series are estimated by GARCH (0, 1) model, and it is used as the measure of uncertainty (Table 4).

Now the standard Granger causality test is employed to explore the direction of causality between inflation and inflation uncertainty. To make sure the results are robust to the choice of lag length, the causality test is performed for three different lag lengths 1, 2, and 12 (Table 5). The results strongly reject the null hypothesis that inflation does not cause inflation uncertainty, and hence inflation is Granger cause of inflation uncertainty. However, the null hypothesis that inflation uncertainty does not cause inflation is not rejected (at 1 and 2 lags). So both *Cukierman-Meltzer Hypothesis* and *Holland Hypothesis* cannot be accepted.

In this regard, the regression of inflation uncertainty on inflation level is estimated (Table 5). Based on the results, until inflation is lower than 2.60 per cent, there is no significant relationship between inflation and inflation uncertainty. But when inflation rate is higher than 2.60 percent threshold, inflation affects inflation uncertainty positively. Therefore, the empirical findings strongly support *Friedman-Ball Hypothesis* during the high-inflation regime; while *Pourgerami-Maskus Hypothesis* is not accepted.

Table 5: Granger Causality

	H_0: Inflation does not Granger-cause inflation uncertainty			*H_0: Inflation uncertainty does not Granger-cause inflation*		
Causality	Lag length	*F*	*P-value*	Lag length	*F*	*P-value*
SIC	1	39.5821	0.0000	1	0.0373	0.8469
HQIC	2	25.9721	0.0000	2	2.2673	0.5715
AIC	12	05.3054	0.0000	12	2.2673	0.0098
	Low-inflation regime ($INF_{t-1} \leq 2.60$)			*High-inflation regime* ($INF_{t-1} \geq 2.60$)		
GARCH	Coefficient	LS S.E.	HCC S.E.	Coefficient	LS S.E.	HCC S.E.
Constant	1.1000	0.1613	0.1755	1.3630	0.2615	0.3914
INF	-0.0420	0.0704	0.0816	0.3612	0.0791	0.1637
R^2= 0.4092						

Source: Research findings

Using SETAR-GARCH model, the behavior of inflationary process is explained by the low-inflation regime, high-inflation regime and uncertainty space between the two regimes which are shown in Fig. 1. As it is clear, the two decades after Iraq-Iran war, it can be approximately distinguished the three sub-periods 1990M05-2000M03, 2000M04-2005M03 and 2005M04-2013M10. Moreover, the average and variance of inflation and uncertainty are calculated for these regimes and sub-periods, which are reported in Table 6. These can be very useful to compare the realities of Iran’s inflation with the results of present model.

In sum, the results of SETAT-GARCH model are consistent with the stylized fact of Iran’s inflation during the two decades after the war. The average of inflation and inflation uncertainty in the second regime are 2.64 and 2.74, respectively; which are significantly larger than the first regime (1.36 and 1.10). In addition, the variances of inflation and uncertainty in the second regime are considerably larger in the second regime than the first regime (4.88 and 7.51 in comparison to 1.53 and 1.66)[1]. Therefore, in the second regime, both the inflation and inflation uncertainty are higher and have more fluctuations than the first regime. The *Friedman-Ball Hypothesis* is confirmed again.

In this regard, it is evident that the period of 2000M04-2005M03 is dominated by the first regime, with low inflation and inflation uncertainty. While the periods of 1990M05-2000M03 and 2005M04-2013M10 are frequently dominated by the second regime, with higher inflation and larger inflation uncertainty.

In the first period (First and Second Five-Year Development Plan of Iran), the fluctuations of inflation are relatively high (Table 6 and Fig. 2). The high and sudden increases in this decade had been as an outcome of structural adjustment policies during the First Development Plan, liberalization of exchange rate and exchange rate crisis in 1993.

The inflation rate exceeds far from the threshold value (44 observations exceeding 2.60 per cent). These peaks are often in the early and late months

1. *F*-test for the equality of means is 26.92 for inflation, and 35.35 for inflation uncertainty. Moreover, *F*-test for the equality of variances is 3.17 for inflation, and 4.51 for inflation uncertainty. All of the *F*-statistics are significant at the 1 percent level (Table 6).

of the year (February, March, and April)[1] that associated with their minimum occurring in the first through fifth months, and hence high inflation causes higher fluctuations. In this decade, the variances of inflation and its volatility are 3.01 and 3.90, respectively which are significantly larger than the ones in the second period (2000M04-2005M03) that are 0.51 and 0.07, respectively (Table 6)[2]. These observations show that inflation behavior in the first decade after the war is dominated by the second regime.

Figure 1: Inflationary Regime of Iran 1990M05-2013M10

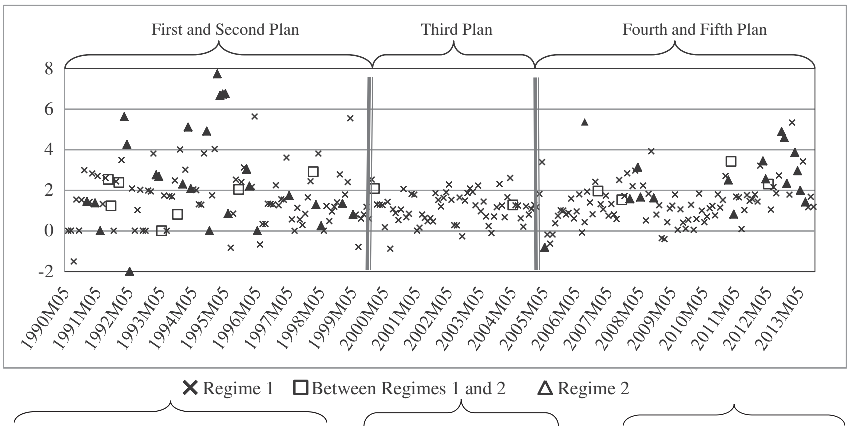


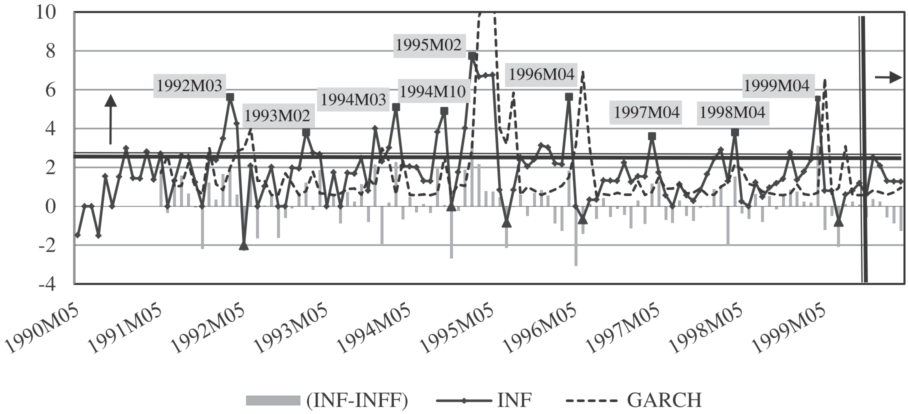
Table 6: Inflation Behaviour

	× Regime 1 (-∞ 2.40]		□Between Regimes [2.41 2.70]		▲ Regime 2 [2.70 ∞)		Equality of regimes 1 and 2	
	INF	CV	INF	CV	INF	CV	F Test	*P-value*
Mean								
	1.3643	□	1.8828	□	2.6413	□	26.9175	0.0000
	□	1.1046	□	1.0980	□	2.7416	35.3462	0.0000
Variance								
	1.5354	□	0.8298	□	4.8760	□	3.1757	0.0001
	□	1.6660	□	0.1822	□	7.5152	4.5110	0.0000

	1990M05 2000M03		2000M04 2005M03		2005M04 2013M10		Equality period 1 to period 2		Equality period 3 to period 2	
	INF	CV	INF	CV	INF	CV	F Test	*p-value*	F Test	*p-value*
Mean										
	1.9124	□	1.0992	□	1.5242	□	9.1022	0.0029	6.6203	0.0110
	□	1.6271	□	0.8192	□	1.0833	9.8214	0.0020	4.6270	0.0330
Variance										
	3.0109	□	0.5079	□	1.3397	□	5.9287	0.0000	2.6380	0.0000
	□	3.9367	□	0.0723	□	0.8602	11.8994	0.0000	54.4555	0.0000

1. Iranian calendar begins after the mid of March.
2. *F*-test for the equality of variances is 5.93 for inflation, and 11.90 for uncertainty, both of which are significant at 1 percent level.

Figure 2: Monthly Inflaiton Rate of Iran 1990M05-199905M05



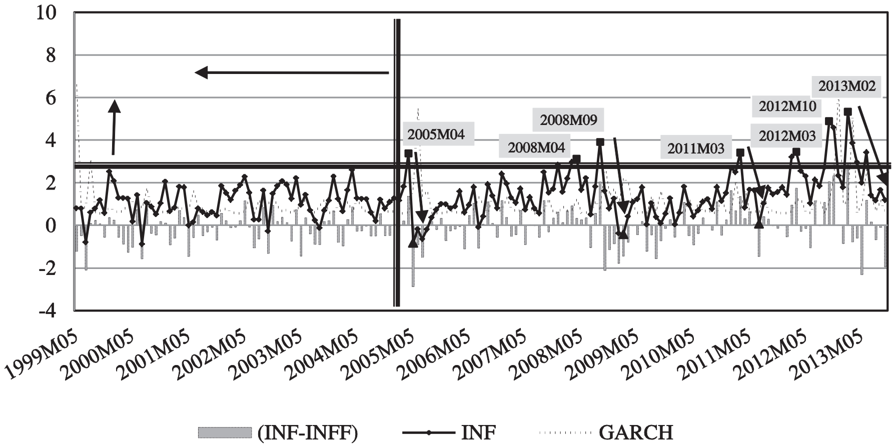
During the five-year period of 2000M04-2005M03, the inflation did not exceed 2.60 percent, and subsequently, economy enjoyed relatively low inflationary fluctuations (Fig. 3). This five-year period is appeared as a period of tranquility and stability which is somehow related to the implementation of the Third Five-Year Development Plan. In this period, the dominant regime was the first regime, and so low inflation caused lower fluctuations. The variance of first regime was 0.91 which is smaller than that of the second regime. Therefore, the inflation before the threshold is less inclined to switch regime and less likely to transmit to the second threshold value. Hence the inflation rate less than 2.60 percent likely remains low.

Finally, in the 9-year period of 2005M04-2013M10, the economy experienced more inflationary fluctuations (Fig. 3). Especially from the late 2011, the inflation higher than the threshold value occurred occasionally that a maximum delay of 5 months contributed to a minimum level of inflation rate. The Fourth Development Plan was similar to the Third Development Plan, but the improper policies and misconduct of government accelerated the fluctuations. The variances of inflation and its volatility were respectively 1.33 and 0.86 in this period, which are significantly larger than those of the second period, 0.51 and 0.07 (Table 6)[1]. These observations are consistent with the

1. *F*-test for the equality of variances is 2.64 for inflation, and 54.45 for uncertainty, which both are significant at 1 percent level.

analysis provided by the second regime that it may lead to unfavorable economic conditions in the future.

Figure 3: Monthly Inflation Rate of Iran 2000M2013-04M10



Conclusions

This paper investigates the relationship between inflation and inflation uncertainty based on a nonlinear framework in Iran. Generally, there are four hypotheses about this relationship. The first one is *Friedman-Ball Hypothesis*. This Hypothesis describes that higher inflation results in increasing uncertainty about money growth and subsequently about future inflation. In contrast, *Pourgerami-Maskus Hypothesis* predicts that an increase in inflation may be associated with lower average uncertainty, since agents invest more resources in forecasting inflation.

On the other hand, *Cukierman-Meltzer Hypothesis* asserts that higher inflation uncertainty will raise inflation rate because the incentives of monetary authority is to stimulate output by surprising monetary policy. Finally, *Holland Hypothesis* argues that, due to the welfare cost of inflation uncertainty, the monetary authority reacts by contracting money growth, and hence higher uncertainty will decrease the average inflation rate.

Using monthly data for the period 1990M05-2013M10, in the present paper, a SETAR-GARCH model is estimated to generate the conditional variance series of inflation as a measure of its uncertainty. Then, Granger method is employed to test causality between inflation and inflation uncertainty. The findings indicate the following results:

First, an asymmetry is observed in the inflation behavior which can be specified by the low- and high-inflation regimes. The inflation rate and its uncertainty in the high-inflation regime are significantly higher and more fluctuating than the other regime. In addition, it is empirically evident that the inflation in the period of 2000-2005 has been completely influenced by the first regime. But, in the periods of 1990-2000 and 2005-2013, economy of Iran is frequently dominated by the high-inflation regime.

These results have noteworthy implications for modelling inflation. If this nonlinear behaviour is ignored, the measure of inflation uncertainty will be inappropriate and also results in an incorrect analysis of the mentioned hypotheses. The nonlinear model allows testing the more accurate inflation-uncertainty hypotheses during different inflationary regimes.

Second, the results show that there is no evidence in favor of *Cukierman-Meltzer* and *Holland Hypotheses*. In other words, inflation uncertainty is not the Granger-cause of inflation. In contrast, one-way positive causal form inflation to uncertainty is significant only in the periods of relatively high inflation, but not in the periods of low inflation. Thus *Friedman-Ball Hypothesis* is accepted, while *Pourgerami-Maskus Hypothesis* is not confirmed.

It is concluded that, when inflation rate switches to the high-inflation regime, it retards output growth both directly and indirectly via the inflation uncertainty channel. Therefore, the incentive for keeping inflation in the range of the first regime is clear. Moreover, this finding confirms the existence of *regime-dependent effect* of inflation on public's expectations about future inflation. Hence, it is crucial that anti-inflation policies are taken in the special months such as February, March and April (the early and late months of the Iranian calendar). Otherwise, high and persistent inflation uncertainty will reduce economic activity and misallocates resources.

Monetary authorities should attempt much more to curb public inflation expectations based on the inflation targeting. An explicit target will be relatively lower than long-run uncertainty based on reducing asymmetric information between the policymaker and public. The government's misconduct and improper policies caused the economy to get away from the goals of the Third Development Plan; therefore, robust policies for targeting inflation, especially in the Sixth Development Plan (2016-2020), must be followed.

Finally, since the results highlight the asymmetric behaviour of inflation-uncertainty, it is suggested that future research should focus on the type of monetary policy rules and stabilization policies that would be consistent with this form of nonlinear behaviour.

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