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A Study of Testing Mean Reversion in the Inflation Rate of Iran's Provinces: New Evidence Using Quantile Unit Root Test

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Abstract

This paper examines the mean-reverting properties of inflation rates for Iran's 25 provinces from 1990:4 to 2017:7. To the end, we use various conventional univariate linear and non-linear unit root tests, as well as a quantile unit root test by Koenker and Xiao (2004). The results of conventional unit root tests indicate that the unit root test null hypothesis is accepted for most of the inflation rate series. Using the quantile unit root test, we found that the null hypothesis of the unit root test is rejected for all inflation rate series globally. But the mean-reverting properties are rejected at low quantiles. The empirical results have important policy implications.

Keywords: Inflation Rate, Iran's Provinces, Quantile Unit Root, Mean Reversion.

JEL Classification: C22, E31.

1. Introduction

Knowing the time-series properties of inflation is a very important issue not only for academic scholars, but also for policymakers; because inflation is often used by most economic theories and empirical studies. One of the main characteristics of inflation is its containing of unit root. Unit root in the inflation rates series implies that shocks on inflation have permanent effects, which will change its statistical characteristics, but if it is described as a stationarity process, it will mean that the shocks impact will be temporary. Whereas some economic theories and empirical works are based on inflation, existing

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unit root in the inflation rate series has several economic and econometric implications.

As noted by Culver and Papell (1997), Lee and Wu (2001), Ho (2008), Narayan and Narayan (2010), and Zhang (2013), theoretical and empirical validity of some theories and hypotheses e.g. sticky-price model by Dornbosch (1979), Philips curves of Calvo (1983), rational expectation model of Cagan (1956), and the Fisher’s (1930) hypothesis base on unit root properties of inflation rate. For example, according to Fisher, in order for real interest rate to be stationary, there should be a one-for-one relation between inflation and nominal interest rates. In other words, empirical validity of Fisher’s hypothesis needs both inflation rate and nominal interest rate to be integrated of order one (Mishkin, 1992). Sticky-price models and inflation require the price level to be stationary. The model of Philips curve needs the process to contain a unit root process and a stationarity inflation process. In contrast, as noted by Narayan and Narayan (2010), the expectation-augmented version of Philips curve needs both wage and inflation to be integrated into orders one.

The empirical studies around unit root properties of inflation provide mixed results, being affected by advances in econometric treatment of unit root or stationarity tests. Empirical studies used both versions of unit root test and stationarity test i.e. univariate and panel frameworks. Most studies that used univariate unit root test did not reject the unit root in the inflation rate series. These studies demonstrated that low power of univariate unit root tests resulted in unit root non-rejection. In contrast, most studies that used panel version of unit root test or stationarity test rejected the unit root in the panel data. For example, Narayan and Narayan (2010) tested the unit root for the inflation rate of 17 OECDs. When they applied the conventional Augmented Dickey and Fuller (1979) (ADF), and Kwiatkowski et.al (1992) (KPSS) test, could not reject the unit root for most of the countries. By using Carrion-i-Silvestre et al. (2005) (CBL) panel stationarity test, which allows for multiple structural breaks, they could not reject the null hypothesis of stationarity for G7. Lee and Wu (2001) examined the mean reversion of inflation rate for 13 OECDs. When they applied the ADF unit root test, they could not reject the null hypothesis of unit root, but using Im, Pesaran, and Shin

(2003) (IPS) panel unit root test, they rejected the null hypothesis of the unit root. Culver and Papell (1997) investigated the unit root properties of 13 OECDs' inflation rate using ADF unit root test, KPSS stationarity test, Perron and Vogelsang (1992) additive outlier unit root test, and Levin and Lin (1992) panel unit root test. Using univariate unit root and stationarity tests, they could reject the unit root only for 4 countries. But when they applied the panel unit root, the null hypothesis of unit root was rejected for the panel of all 13 countries. Lee and Chang (2007) provided the mean reversion hypothesis for 19 OECD countries using both univariate and panel version of Lagrange Multiplier (LM) unit root. They found results in favor of stationarity, and demonstrated that the most shocks to inflation rates were transitory. Ho (2008) examined the unit root properties of inflation rate applying the panel unit root test of 19 OECDs. Using IPS panel unit root, he rejected the null hypothesis. But when he applied the Chang's (2002) panel unit root test that used nonlinear instrument variable estimator and account for cross-sectional correlation, could not reject the null hypothesis of unit root test.

According to Tsong and Lee (2011), all univariate, panel unit root, and stationary tests assume symmetric inflation adjustment towards their long-run equilibrium, while the inflation rates series may behave asymmetrically related to negative and positive shocks. Another important property of inflation rates series is that their distribution is non-normal and often leptokurtic (Charemza and Hristova, 2005). According to Koenker and Xiao (2004), the conventional univariate unit root tests either have poor power performance, or tend to bias in favor of a unit root when the series has non-normal distribution. In order to overcome two shortcomings of conventional unit root tests i.e. controlling asymmetric behavior and non-normal distribution, recent studies applied quantile unit root test.

Tsong and Lee (2011) examined the inflation dynamic behavior in 12 OECDs using quantile unit root test of Koenker and Xiao (2004). They found evidence in favor of asymmetric mean-reverting properties in the inflation rate series. So, negative shocks have transitory effects, while positive shocks have long-lasting effects. Wolters and Tillman (2015) examined the unit root hypothesis over different quantile of inflation rate series of US as well as the possibility of structural changes. They found a structural break in the early 1980s. So, prior to 1980s, the shocks to inflation rates series have persistent effects, while after 1980s, the shocks disappeared in the short-run. Si and Li (2017) examined mean-reverting properties in the inflation rates of 7 Eastern European countries using Fourier quantile unit root test by Bahmani-Oskooee et al. (2016). Applying the test, they found stationarity at each quantiles for Czech Republic, Bulgaria and Lithuania, while the inflation rates of Poland, Estonia, Romania, and Latvia, contained a unit root within some quantiles. Bolat et al. (2017) analyzed inflation rates dynamics in the Middle East and North Africa countries using quantile unit root test. The results indicated that MENA's inflation rates showed different behavior at each quantiles, and thus in most of them, only negative shocks did not have long-lasting effects. Gaglianone et al. (2018) examined a unit root test in the inflation rates of Brazil using quantile auto-regression modelling. They found that the inflation rates showed asymmetric behavior to positive and negative shocks, and the positive shocks seemed to have greater dissipation time than the negative shocks.

This paper is to investigate the inflation rates stochastic behavior of Iran's provinces applying the quantile unit root test. Iranian economy has experienced a high double-digit inflation rate in most after years of 1979 revolution. Thus, one of the main policies of all presidents was control for the inflation rate. Applying the quantile unit root test, this paper will analyze the inflation rates asymmetric behavior of Iran's provinces.

The remainder of this paper is organized as follows. Section 2 discusses the inflation rate dynamics in the Iranian economy. The methodology is provided in Section 3. Section 4 presents the empirical results, and Section 5 concludes the paper.

2. Dynamics of Inflation Rate in the Iranian Economy

Iranian economy has experienced the persistence of stagflation, meltdown economic growth with high double-digit inflation rate, economic sanctions, closed economy with considerable trade barriers, and frequent and deep oil price shocks from the 1979 revolution onwards. Figure 1 displays the dynamics of consumer price index (CPI) and inflation rates in the Iranian economy. As can be seen, inflationary process in Iran economy showed that the consumer price index grew more than 2,719,327 percent over the period 1936–2017, 79,883 percent over the period from 1978–2017, and 3,300 percent for the period of 1936–1978[1]. In other words, inflationary process in Iran began from mid-1970s or after the first oil price shock. According to Loony (1985, P: 1), in retrospect, the development of inflation in Iran especially after 1973, together with the government inability to stabilize the price level were undoubtedly major economic causes of the 1979 revolution. This process continued after the 1979 revolution. According to Bahmani–Oskooei (1995: 61), after the revolution in 1978–1979, Iran has experienced an inflation rate of more than 600% over the period from 1978–1990. Even an ordinary person in Iran, who knows nothing about economics, wonders why prices grow much faster during the post-revolutionary period than they were in the pre-revolutionary period.

Iranian economy has experienced two-digit inflation rate since the revolution 1979 (except the two years of 1985 and 1990 and the recent years of 2016 and 2017), and after an inflation peak to 49.4 percent in 1995, anti-inflationary policies were implemented to control inflation in subsequent years. However, in recent years, after President Ahmadinejad came to power in 2005, due to implementation of subsidy reform that resulted in increasing energy prices, populist economic policies in order for poverty reduction and increasing equality[2], and the intensification of international trade and financial sanctions by the west since 2012 led to a significant increase in inflation and stagnation in Iran's economy.

In recent years, one of the main policies of president Rouhani was to control the inflation rate. So that he could reduce the high inflation rate of 34% in 2013 to 9% in 2017.

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1. The real GDP grew 820 percent over the period 1959–2012, 386 percent over the period from 1959–1978, and 89.34 percent over the period 1978–2012.
2. For example, in order for poverty reduction and creating equality, the rising 9th government revenues due to oil shock of 2007–2008 were absorbed by a higher spending, and were made available to individuals and companies via systems such as "quick-impact loans", which were diverted to the housing market due to the inadequate private and public investment (Kandil and Mirzaie, 2017).

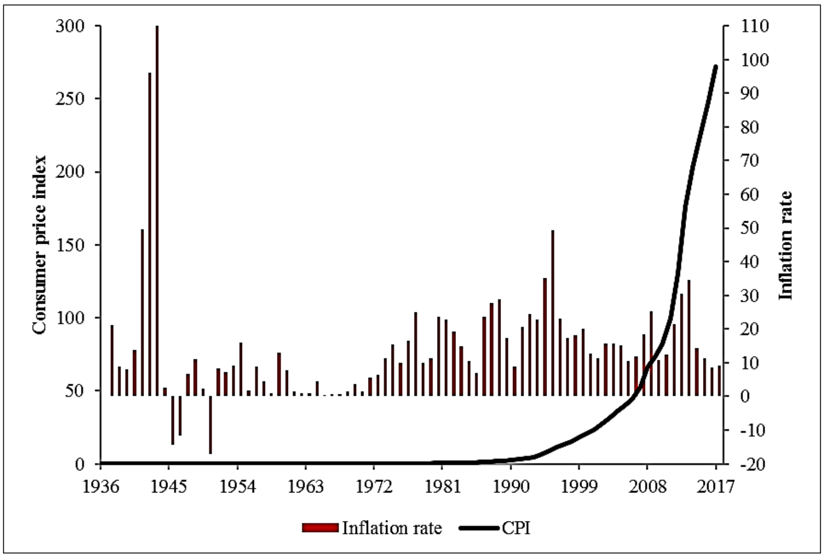

Figure 1: The Dynamics of Iran's CPI and Inflation Rate
Source: Central bank of Iran.

In order to analyze the mean-reverting properties of inflation rates of Iran's provinces, there were provided the monthly consumer price index (CPI) dataset of 25 provinces over the period from 1990:4 to 2017:7[1]. The provinces are prepared in the first column of Table 1. The inflation rates can be calculated as the Equation (1):

$$\pi_{it} = (\ln(CPI_{it}) - \ln(CPI_{it-12})) * 100 \quad (1)$$

where π_{it} is the inflation rate of province i in month t.

Table 1 illustrates the statistical properties of inflation rate of Iran's provinces. The average inflation rate over the sub-periods 1991–1995, 1996–2000, …, 2016–2017 indicates that the tolerance is between 24%–28% over the period 1991–1995, and over the three next sub-periods i.e. 1996–2000, 2001–2005, and 2006–2010 the tolerance is between 12%–19%. But from 2010 onwards, due to the expansionary policies over the two terms of president Ahmadinejad, along with the European economic sanction, Iran's provinces experienced the inflation rates between 19%–22% over the period from 2011–2015. Over the two recent years, 2016 and 2017, the inflation rate reduced to

1. Dataset were collected from the central bank of Iran.

6%–10% across the provinces. Over the period from 1991–2017, the provinces i.e. Kurdistan, Hormozgan, Chahar-Mahaal and Bakhtiari, Ilam, and Lorestan experienced the highest inflation rate, and the provinces i.e. West Azerbaijan, Mazandaran, Tehran, Sistan and Baluchestan, and Bushehr experienced the lowest inflation rates.

Over the period from 1991–2017, the provinces i.e. Lorestan, Mazandaran, Kerman, Isfahan, and Tehran had the lowest inflation rate volatility, and in contrast, the provinces i.e. Kohgiluyeh and Boyer-Ahmad, Khuzestan, Bushehr, Hormozgan, and Fars experienced the highest volatility. The inflation rate volatility is one of the inflation source in the post-revolutionary Iran.

Table 1: Statistical Description of Inflation Rate of Iran's Provinces

Provinces	Average inflation rate over sub-periods							Standard Deviation	Kurtosis	Skewness	P-value of Jarque-Bera normality test
	1991-1995	1996-2000	2001-2005	2006-2010	2011-2015	2016-2017	1991-2017				
Azerbaijan, East	25.369	19.112	11.706	14.669	21.303	7.991	17.738	8.152	1.108	1.059	0.000
Azerbaijan, West	25.306	17.296	12.000	14.230	22.281	7.946	17.538	8.271	1.533	1.247	0.000
Ardabil	24.945	17.489	13.515	14.517	21.587	6.876	17.655	8.682	2.282	1.417	0.000
Isfahan	25.981	17.909	13.168	14.401	21.237	8.771	17.881	7.952	1.383	1.221	0.000
Ilam	24.142	18.068	14.428	14.721	22.432	6.454	17.967	8.711	1.368	1.123	0.000
Bushehr	25.820	17.358	12.015	12.349	20.473	7.221	16.901	9.102	2.133	1.392	0.000
Tehran	25.647	17.748	13.432	14.077	19.277	9.975	17.479	7.445	1.542	1.161	0.000
Chahar-Mahaal and Bakhtiari	26.477	18.480	12.396	14.767	21.278	8.759	18.009	8.312	1.450	1.253	0.000
Khorasan	26.067	18.166	12.374	14.141	22.052	7.308	17.812	8.533	1.671	1.327	0.000
Khuzestan	25.435	19.680	12.410	13.548	21.038	8.722	17.772	9.103	1.428	1.250	0.000
Zanjan	25.256	18.503	13.267	13.596	21.215	7.595	17.654	8.565	1.228	1.079	0.000
Semnan	25.305	17.539	13.808	13.585	21.782	8.983	17.772	8.242	2.069	1.364	0.000
Sistan and Baluchestan	25.498	19.025	10.628	13.595	21.679	6.790	17.335	8.713	0.378	0.947	0.000
Fars	27.399	17.925	13.039	13.099	21.250	8.920	17.880	8.797	1.675	1.290	0.000
Kurdistan	25.594	18.164	14.819	14.359	21.769	7.489	18.189	8.241	0.642	0.945	0.000
Kerman	26.111	18.194	12.362	13.282	21.524	7.928	17.597	7.962	0.758	1.096	0.000
Kermanshah	24.818	17.909	14.078	14.172	21.477	6.106	17.686	8.223	1.434	1.147	0.000
Kohgiluyeh and Boyer-Ahmad	28.069	17.015	12.745	13.338	21.274	9.066	17.831	9.741	3.118	1.655	0.000
Gilan	26.022	18.242	12.674	14.110	20.896	9.546	17.785	8.453	2.223	1.411	0.000
Lorestan	25.504	18.292	13.629	14.709	21.214	7.584	17.938	8.097	1.343	1.142	0.000
Mazandaran	24.720	18.568	11.770	14.561	21.085	8.983	17.528	8.081	1.592	1.303	0.000
Markazi	25.358	18.257	13.252	14.257	21.080	8.059	17.751	8.200	0.897	1.035	0.000
Hormozgan	28.082	17.046	13.447	14.058	21.043	8.875	18.054	9.097	1.350	1.105	0.000
Hamedan	25.655	17.138	12.518	15.062	22.267	7.501	17.797	8.775	1.349	1.166	0.000
Yazd	25.865	18.116	11.596	14.131	21.709	8.667	17.633	8.430	1.381	1.220	0.000

3. Methodology

In this paper, analyzing the mean-reverting of the inflation rate is conducted using the quantile unit root tests. The inflation rate, π, is generated as the Equation (2):

$$\pi_t = \beta_0 + \xi_t \quad (2)$$

where β_0 is the intercept, and ξ_t is the error term. We define demean version of π as $\bar{\pi}$. In order to examine the null hypothesis of the unit root in τ_{th} conditional quantile of $\bar{\pi}$, we specify and estimate the following quantile regression:

$$\psi_{\bar{\pi}_t}(\tau|\bar{\pi}_{t-1}) = \alpha_0(\tau) + \rho_1(\tau)\bar{\pi}_{t-1} + \sum_{k=1}^{k=l} \alpha_{1+k}(\tau)\Delta\bar{\pi}_{t-k} + \vartheta_t \quad (3)$$

where $\psi_{\bar{\pi}_t}(\tau|\bar{\pi}_{t-1})$ is the τ_{th} quantile of $\bar{\pi}_t$, conditional on the past information set, $\bar{\pi}_{t-1}$, and $\alpha_0(\tau)$ is the τ_{th} conditional quantile of ϑ_t. The maximum lags were set at 18, and the optimum lags (k^*) were selected by the Akaike's information criterion (AIC). $\alpha_0(\tau)$, $\rho_1(\tau)$, $\alpha_2(\tau)$, …, $\alpha_{k+1}(\tau)$ were estimated by minimizing sum of asymmetrically weighted absolute deviations:

$$min \sum_{t=1}^{n} \left(\tau - I\left(\bar{\pi}_t < \alpha_0(\tau) + \rho_1(\tau)\bar{\pi}_{t-1} + \sum_{k^*=1}^{k^*=l} \alpha_{1+k^*}(\tau)\Delta\bar{\pi}_{t-k^*} \right) \right) \Bigg| \bar{\pi}_t - \pi_0(\tau) + \rho_1(\tau)\bar{\pi}_{t-1} + \sum_{k^*=1}^{k^*=l} \alpha_{1+k}(\tau)\Delta\bar{\pi}_{t-k^*} \Bigg| \quad (4)$$

where I=1 if $\bar{\pi}_t < (\alpha_0(\tau) + \rho_1(\tau)\bar{\pi}_{t-1} + \sum_{k^*=1}^{k^*=l} \alpha_{1+k^*}(\tau)\Delta\bar{\pi}_{t-k^*})$, and I=0 otherwise. In order to test a unit root of $\bar{\pi}_t$ within the τ_{th} quantile, Koenker and Xiao (2004) suggested the following *t ratio* statistic:

$$t_n(\tau_i) = \frac{\hat{f}(F^{-1}(\tau_i))}{\sqrt{\tau_i(1-\tau_i)}} (\chi'_{-1} P_W \chi_{-1})^{1/2} (\widehat{\rho_1}(\tau_i) - 1) \quad (5)$$

In Equation (5), χ_{-1} is the vector of lagged dependent variable ($\bar{\pi}_{t-1}$), and P_W is the projection matrix onto the space orthogonal to $W = (1, \Delta\bar{\pi}_{t-1}, \ldots, \Delta\bar{\pi}_{t-k})$. In order to obtain a consistent estimator of $\hat{f}(F^{-1}(\tau_i))$, the Equation (6) was proposed by Koenker and Xiao (2004):

$$\hat{f}\left(F^{-1}(\tau_i)\right) = \frac{(\tau_i - \tau_{i-1})}{W'\left(\varrho(\tau_i) - \varrho(\tau_{i-1})\right)} \tag{6}$$

where $\varrho(\tau_i) = (\alpha_0(\tau_i), \rho(\tau_i), \alpha_2(\tau_i), \ldots, \alpha_{1+k^*}(\tau_i))$, and $\tau_i \in [\underline{d}, \overline{d}]$. In this paper, it was set $\underline{r} = 0.1$, and $\overline{r} = 0.9$. To test the unit root hypothesis over a range of quantiles, Koenker and Xiao (2004) recommended the following quantile Kolmogorov–Smirnov (QKS) test statistics:

$$QKS = \sup_{\tau_i \in [\underline{r}, \overline{r}]} |t_n(\tau)| \tag{7}$$

the limiting distributions of $t_n(\tau_i)$ and QKS test statistics are nonstandard, which depend on the nuisance parameters. Hence, we use Koenker and Xiao (2004) re-sampling procedures to drive the exact critical values.

4. Empirical Results

As a benchmark, we apply four conventional univariate unit root tests i.e. ADF, DF-GLS, PP, and Ng-Perron, and the two nonlinear unit root tests of Kapetanios et al. (2003), and Sollis (2009). In order to test the null hypothesis of unit root, the test statistics were compared to the critical values at 5% for all unit root tests. Table 2 provides the unit tests' results without a trend function. There were prepared the results for ADF, DF-GLS, PP, and NP tests in panel A of Table 2. In the ADF and DF-GLS, it is selected the optimum lag order of the test based on the recursive t-statistic, as suggested by Campbell and Perron (1991). The ADF rejects the null hypothesis of unit root, only for Hormozgan. The DF-GLS unit root test rejects the null hypothesis of unit root for 8 provinces i.e. West Azerbaijan, Isfahan, Tehran, Chahar-Mahaal and Bakhtiari, Sistan and Baluchestan, Fars, Kohgiluyeh and Boyer-Ahmad, and Hormozgan. The PP unit root test rejects the null hypothesis of unit root for 9 provinces i.e. West Azerbaijan, Khuzestan, Semnan, Kohgiluyeh and Boyer-Ahmad, Gilan, Mazandaran, Markazi, Hormozgan, and Yazd. The NP unit root test rejects the null hypothesis for 13 provinces i.e. West Azerbaijan, Isfahan, Tehran, Chahar-Mahaal and Bakhtiari, Zanjan, Semnan, Fars, Kerman, Kohgiluyeh and Boyer-Ahmad, Gilan, Markazi, Hormozgan, and Yazd. Results of two non-linear unit root tests are prepared in the panel B of Table 2. As can be seen, according to both unit root tests, the null hypothesis of unit root is rejected for 5 provinces' inflation rate series i.e. Ardabil, Bushehr, Zanjan, Mazandaran, and Hormozgan.

The results of ADF, DF-GLS, PP, NP, KSS, and AESTAR indicate that there is not a mean reversion of inflation rate in most of the provinces. This result is consistent with that of the literature, and is due to the low power of these univariate unit root tests when the inflation rates series are highly persistent. Another reason for the low power of the univariate unit roots may be the non-normal distribution of the inflation rate series. As can be seen in Table 1, the p-values of Jarque-Bera normality test are 0.000, and thus, the null hypothesis of normal distribution is rejected for all the inflation rate series at 1% significant level.

In order to show the high degree of persistence in the inflation rates series, the persistence can be measured through the half-life[1], and for calculating the half-life, following to Rapach and Wohar (2004), we suppose that the inflation rates series (π_t) are generated as follows:

$$\pi_t = \alpha + \sum_{k=1}^{k=p} \beta_k \pi_{t-k} + \varepsilon_t \tag{8}$$

In order for calculating the half-life, first the sum of the AR coefficients $(\beta = \sum_{k=1}^{k=p} \beta_k)$ is calculated. Then, using the cumulative impulse response function, the half-life is calculated. In order for constructing confidence intervals for β, Rapach and Wohar (2004) suggested Hansen's (1999) methodology. Table 2 presents the results for half-life. We classify the Iran's provinces according to their half-lives to two groups: provinces with half-life less than 1 years (first group), and provinces with half-life greater than or equal to 1 year (second group). Results of half-life show that a shock to only the inflation rates of Hormozgan will be dissipated by about 1 year. Results of unit root tests in the Table 2 indicate that all conventional linear and non-linear unit root tests reject the null hypothesis of unit

1. Half-life implies the number of years required for a shock to inflation rates series to dissipate by one-half.

root inflation rate of Hormozgan. A shock to the inflation rates of other provinces requires a time period between 1–2 years to be dissipated by one-half. The results of the confidence intervals for half-life (the figures in the bracket) show that confidence intervals are very wide for the half-life of all provinces. Results show a high degree of persistence in the inflation rate series.

Table 2: The Results of Conventional Linear and Non-linear Unit Root Tests

Province	**Panel A: Conventional unit root tests**				**Panel B: Nonlinear unit root test**		**Panel C: Half life**
	ADF	**DF-GLS**	**PP**	**NP**	**KSS**	**Sollis**	
Azerbaijan, East	-1.472	-1.484	-2.803	-7.662	-2.679	3.782	17.827 [16.216 , 24]
Azerbaijan, West	-2.215	-1.982**	-2.9**	-11.548**	-2.076	2.265	18.177 [15.908 , 24]
Ardabil	-2.312	-1.902	-2.747	-8.058	-3.441**	7.018**	19.716 [17.923 , 24]
Isfahan	-1.859	-1.942**	-2.511	-12.981**	-2.771	4.219	18.792 [15.512 , 24]
Ilam	-2.425	-1.743	-2.642	-7.72	-2.523	3.395	19.562 [18.275 , 24]
Bushehr	-2.152	-1.777	-2.779	-7.679	-3.556**	6.685**	20.040 [18.583 , 24]
Tehran	-2.363	-1.969**	-2.868	-11.245**	-2.787	4.079	22.062 [18.912 , 24]
Chahar-Mahaal and Bakhtiari	-2.145	-2.228**	-2.532	-13.221**	-2.329	2.988	19.525 [16.806 , 24]
Khorasan	-2.131	-1.675	-2.645	-6.958	-2.742	3.948	21.386 [18.775 , 24]
Khuzestan	-2.705	-1.729	-2.989**	-6.051	-2.715	3.888	19.428 [16.689 , 24]
Zanjan	-1.99	-1.66	-2.785	-8.227**	-3.095**	5.303**	20.499 [18.228 , 24]
Semnan	-2.244	-1.795	-2.901**	-8.444**	-2.694	3.843	18.662 [15.944 , 24]
Sistan and Baluchestan	-2.186	-2.032**	-2.202	-7.573	-2.365	3.1	19.705 [17.242 , 24]
Fars	-2.122	-1.995**	-2.443	-9.262**	-2.489	3.288	20.757 [18.998 , 24]
Kurdistan	-2.233	-1.782	-2.534	-6.903	-2.35	2.876	19.791 [17.774 , 24]
Kerman	-1.735	-1.775	-2.39	-8.469**	-1.744	2.133	18.608 [15.342 , 24]
Kermanshah	-2.135	-1.682	-2.71	-7.699	-2.6	3.656	21.234 [18.472 , 24]
Kohgiluyeh and Boyer-Ahmad	-2.468	-2.471**	-2.97**	-16.967**	-2.272	2.691	16.792 [13.867 , 24]
Gilan	-2.028	-1.604	-2.937**	-8.205**	-2.67	3.99	19.441 [17.570 , 24]
Lorestan	-2.268	-1.711	-2.87	-8.098	-2.858	4.483	19.254 [15.970 , 24]
Mazandaran	-2.012	-1.55	-2.933**	-7.804	-3.135**	5.309**	19.435 [17.615 , 24]
Markazi	-1.891	-1.61	-2.924**	-8.459**	-2.87	4.36	18.965 [15.530 , 24]
Hormozgan	-3.056**	-2.849**	-3.229**	-11.085**	-3.79**	7.564**	11.820 [11.545 , 24]
Hamadan	-2.133	-1.503	-2.915**	-5.832	-2.87	4.399	20.639 [18.232 , 24]
Yazd	-2.007	-1.765	-2.625	-9.457**	-2.051	2.761	18.483 [14.718 , 24]

Note: (1) There were determined the optimum lag(s) for ADF, DF-GLS, PP, NG, KSS and Sollis (2009) unit root tests based on the AIC information criteria. In the NG and PP tests, the bandwidth was selected by the Bartlett Kernel. (2) ** denotes that the null hypothesis of unit root is rejected at 5% significant level.

To test the low power of conventional linear and non-linear unit root tests, the quantile unit root test was applied. Results are provided in Table 3. The optimum lags (p*) are prepared in the second column, and are selected using AIC information criteria. Number of optimum lags varies from 14 to 16. So, for 3 out of 25 inflation rate series 14 lags are selected, for 4 out of 25 inflation rate series 15 lags are selected, and for other inflation rate series 16 lags are selected.

Comparing the QKS test statistics in third column with its critical values in columns 4–6 indicate that the null hypothesis of unit root is rejected for inflation rate series of two provinces i.e. Sistan and Baluchestan, and Kerman, for two inflation rate series of East Azerbaijan and Isfahan, the null hypothesis is rejected at 5% significant level, and for other inflation rate series, the null hypothesis is rejected at 1% statistically significant level. As seen, using quantile unit root tests, the null hypothesis of a unit root is rejected for all inflation rate series at conventional significant level. Thus, the mean reversion hypothesis in the inflation rate of Iran's provinces is not rejected over the quantiles [0.1, 0.9].

In order to analyze the unit root behavior in each quantile, the p-values of $t_n(\tau_i)$ test statistics were used. Results are provided in panel B of Table 3. Also, the values of autoregressive coefficient $(\rho_1(\tau))$ at each quantile are illustrated in Figure 1. The p-values of $t_n(\tau_i)$ test statistics indicate that the null hypothesis of unit root is rejected only over the quantiles [0.1, 0.3] of inflation rate series of provinces i.e. Isfahan, Chahar-Mahaal and Bakhtiari, Kermanshah, Mazandaran, and Markazi. Yet, the null hypothesis of unit root is not rejected in the other quantiles of the aforementioned inflation rate series. The inflation rate series of West Azerbaijan, Zanjan, Sistan and Baluchestan, Fars, Kerman, Gilan, and Hamadan behave as a stationary process over the quantiles [0.1, 0.4] and as a non-stationary process over the quantiles greater than 0.4. 12 out of 25 inflation rate series i.e. East Azerbaijan, Ardabil, Ilam, Bushehr, Tehran, Khorasan, Khuzestan, Semnan, Kurdistan, Kohgiluyeh and Boyer-Ahmad, Hormozgan, and Yazd display a stationary behavior over the quantiles [0.1, 0.5], and a non-stationary behavior over quantiles greater than 0.5. The inflation rate series of Lorestan show stationary behavior over quantiles [0.1, 0.4] and quantile [0.6], and over other quantiles behaves as process with a unit root.

According to the estimated autoregressive coefficient ($\rho_1(\tau)$) in Equation (3), which is displayed in Figure 1, the estimated values for all inflation rate series indicate upward straight-line or concave pattern over the quantiles [0.1, 0.9]. Results showed that the negative shocks to inflation rate series of all provinces were dissipated in the short-run. While positive shocks to inflation rate series are more persistent, and have long-lasting effects. According to computed half-life results, which are illustrated in panel C of table 3, at quantile [0.1], the half-life of negative shock to inflation rates varies from 5 months (for Ilam, Chahar-Mahaal and Bakhtiari, Semnan, Kohgiluyeh and Boyer-Ahmad, Lorestan, and Hormozgan) to 11 months (for West Azerbaijan, Kerman, and Gilan). At quantile [0.2], the half-life of negative shock to inflation rates varies from 6 months (for Hormozgan and Yazd) to 12–13 months (for Khuzestan, Sistan and Baluchestan, and Lorestan). At quantile [0.3], the half-life of negative shock to inflation rates varies from 7–8 months (for Semnan, Kohgiluyeh and Boyer-Ahmad, and Hormozgan) to 12–13 months (for Isfahan, Sistan and Baluchestan, Kurdistan, and Kermanshah). At quantile [0.4], the half-life of negative shock to inflation rates varies from 8–10 months (for Semnan and Kohgiluyeh and Boyer-Ahmad) to 21–22 months (for East Azerbaijan, Chahar-Mahaal and Bakhtiari, Isfahan, and Gilan). At quantile [0.5], the half-life of negative shock to inflation rates varies from 11–14 months (for Bushehr, Semnan, and Kohgiluyeh and Boyer-Ahmad) to 29–31 months (for Gilan and Markazi).

In Figure 2, the inflation rates of 25 provinces were plotted, and the dates were shadowed. According to the quantile unit root test, the mean reversion is not rejected. As can be seen, almost in all provinces, when they experience low inflation rate, there is mean-reverting properties in the inflation rate series, and shock disappears in short-run. In contrast, when they experience high inflation rates, the positive shocks have long-run effects.

Table 3: Results of Quantile Unit Root Tests

Province		Azerbaijan, East	Azerbaijan, West	Ardabil	Isfahan	Ilam	Bushehr	Tehran	Chahar-Mahaal and Bakhtiari	Khorasan
lags		16	16	16	16	16	16	16	14	15
Panel A: QKS test statistics and Critical values	Test	3.564	5.137	4.176	3.385	6.038	4.849	6.464	5.594	4.519
	90%	2.956	2.988	3.028	2.911	3.017	3.004	2.992	3.052	3.022
	95%	3.119	3.249	3.308	3.242	3.297	3.21	3.204	3.246	3.3
	99%	3.888	3.537	3.799	3.763	4.01	3.669	3.638	4.07	3.764
Panel B: P-values of $t_n(\tau_i)$	0.1	0.012	0.032	0.000	0.006	0.000	0.000	0.000	0.000	0.004
	0.2	0.000	0.000	0.000	0.004	0.000	0.000	0.000	0.006	0.000
	0.3	0.008	0.000	0.000	0.038	0.000	0.000	0.000	0.068	0.000
	0.4	0.042	0.006	0.046	0.218	0.002	0.000	0.000	0.256	0.000
	0.5	0.058	0.174	0.072	0.206	0.054	0.000	0.076	0.182	0.018
	0.6	0.278	0.422	0.324	0.424	0.652	0.186	0.236	0.366	0.414
	0.7	0.534	0.826	0.832	0.742	0.794	0.418	0.928	0.888	0.928
	0.8	0.964	0.812	0.800	1.000	1.000	0.992	1.000	0.976	0.968
	0.9	0.938	0.986	0.990	1.000	1.000	0.998	0.982	0.994	0.972
Panel C: Half lives	0.1	9	10	7	7	5	7	9	5	8
	0.2	9	8	9	10	7	9	8	8	10
	0.3	13	12	11	14	9	12	10	13	12
	0.4	21	12	19	22	12	12	13	21	14
	0.5	24	23	22	24	19	14	25	20	18
	0.6	34	36	36	36	57	24	34	30	43
	0.7	46	173	693	99	138	36	∞	∞	∞
	0.8	∞	231	231	∞	∞	∞	∞	∞	∞
	0.9	∞	∞	∞	∞	∞	∞	∞	∞	∞

Kohgiluyeh and Boyer-Ahmad	Kermanshah	Kerman	Kurdistan	Fars	Sistan and Baluchestan	Semnan	Zanjan	Khuzestan	**Province**	
16	16	16	15	16	15	16	14	16	**lags**	
5.53	3.761	2.996	5.499	5.635	3.12	5.875	4.227	4.184	**Test**	**Panel A: QKS test statistics and Critical values**
3.015	2.952	2.993	3.01	2.871	3.046	2.855	3.072	2.917	**90%**	
3.314	3.185	3.281	3.212	3.1	3.348	3.039	3.301	3.345	**95%**	
4.146	3.754	3.825	3.72	3.647	4.106	3.5	3.85	4.01	**99%**	
0.022	0.002	0.082	0.000	0.000	0.006	0.000	0.002	0.002	**0.1**	**Panel B: P-values of $t_n(\tau_i)$**
0.000	0.000	0.006	0.018	0.000	0.020	0.000	0.000	0.016	**0.2**	
0.000	0.010	0.014	0.042	0.006	0.028	0.000	0.004	0.004	**0.3**	
0.000	0.146	0.022	0.026	0.004	0.098	0.000	0.000	0.000	**0.4**	
0.008	0.140	0.220	0.030	0.192	0.176	0.018	0.202	0.022	**0.5**	
0.514	0.664	0.316	0.202	0.556	0.490	0.440	0.246	0.216	**0.6**	
0.928	0.502	0.702	0.446	0.906	0.986	0.874	0.822	0.788	**0.7**	
0.972	0.994	0.976	0.718	1.000	0.960	1.000	0.984	0.984	**0.8**	
0.998	0.986	0.966	0.988	1.000	0.988	0.998	0.990	1.000	**0.9**	
5	7	11	6	6	9	5	8	6	**0.1**	**Panel C: Half lives**
7	9	10	11	7	13	7	10	13	**0.2**	
7	14	13	14	12	15	8	12	13	**0.3**	
8	19	16	14	15	19	10	14	13	**0.4**	
11	20	25	16	25	21	14	27	18	**0.5**	
40	49	29	22	43	33	27	25	27	**0.6**	
∞	36	69	26	∞	∞	∞	173	173	**0.7**	
∞	∞	∞	69	∞	∞	∞	∞	∞	**0.8**	
∞	∞	∞	∞	∞	∞	∞	∞	∞	**0.9**	

Province		Gilan	Lorestan	Mazandaran	Markazi	Hormozgan	Hamadan	Yazd
lags		16	16	15	14	16	16	16
Panel A: QKS test statistics and Critical values	**Test**	4.301	3.542	5.767	4.231	4.77	4.906	4.024
	90%	3.005	2.895	3.05	3.067	3.01	2.988	2.943
	95%	3.186	3.103	3.286	3.346	3.262	3.292	3.174
	99%	3.718	3.524	3.776	3.699	3.829	3.842	3.581
Panel B: P-values of $t_n(\tau_i)$	**0.1**	0.022	0.008	0.000	0.000	0.002	0.000	0.010
	0.2	0.000	0.036	0.000	0.000	0.000	0.000	0.000
	0.3	0.000	0.012	0.004	0.018	0.000	0.004	0.002
	0.4	0.098	0.046	0.112	0.134	0.038	0.036	0.016
	0.5	0.336	0.116	0.194	0.394	0.074	0.226	0.034
	0.6	0.410	0.052	0.434	0.764	0.822	0.490	0.786
	0.7	0.768	0.498	0.512	0.854	0.818	0.888	0.900
	0.8	0.996	0.980	0.958	0.906	0.740	0.960	0.994
	0.9	0.968	0.964	0.998	0.986	0.998	1.000	0.976
Panel C: Half lives	**0.1**	10	5	6	6	5	7	6
	0.2	9	12	7	7	6	9	6
	0.3	11	12	13	12	8	12	9
	0.4	21	15	20	19	14	19	12
	0.5	29	18	25	31	16	27	17
	0.6	36	15	36	99	138	40	115
	0.7	115	31	36	231	173	∞	∞
	0.8	∞	∞	∞	∞	63	∞	∞
	0.9	∞	∞	∞	∞	∞	∞	∞

Note: The P-values for $t_n(\tau_i)$ and critical values for F-QKS statistics were calculated through bootstrapping procedure, by 5000 replications.

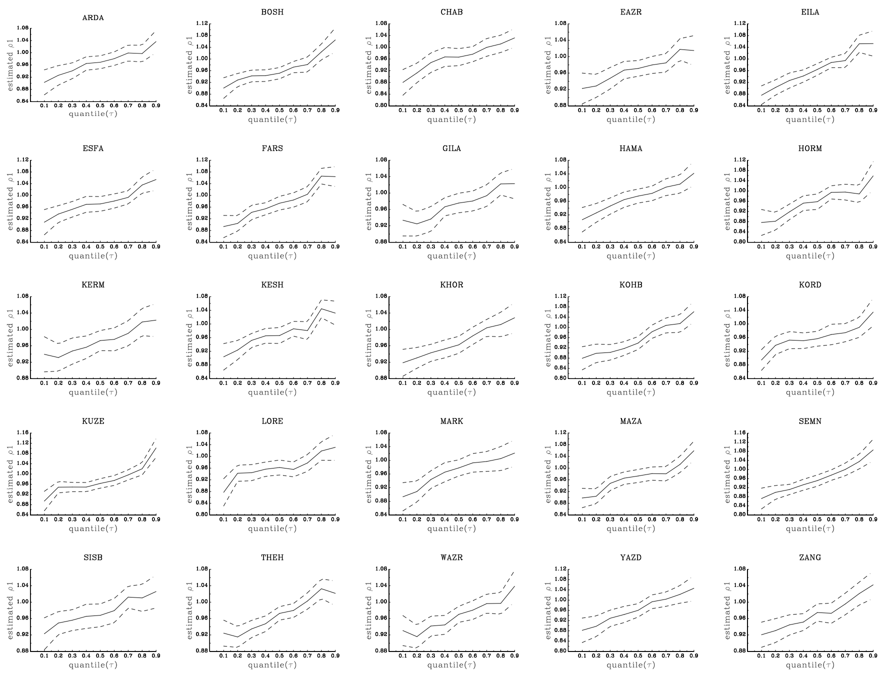

Figure 2: Quantile Autoregressive Coefficient ($\rho_1(\tau)$)

Note: Solid lines are the values of $\rho_1(\tau)$, and dashed lines are 95% confidence intervals.

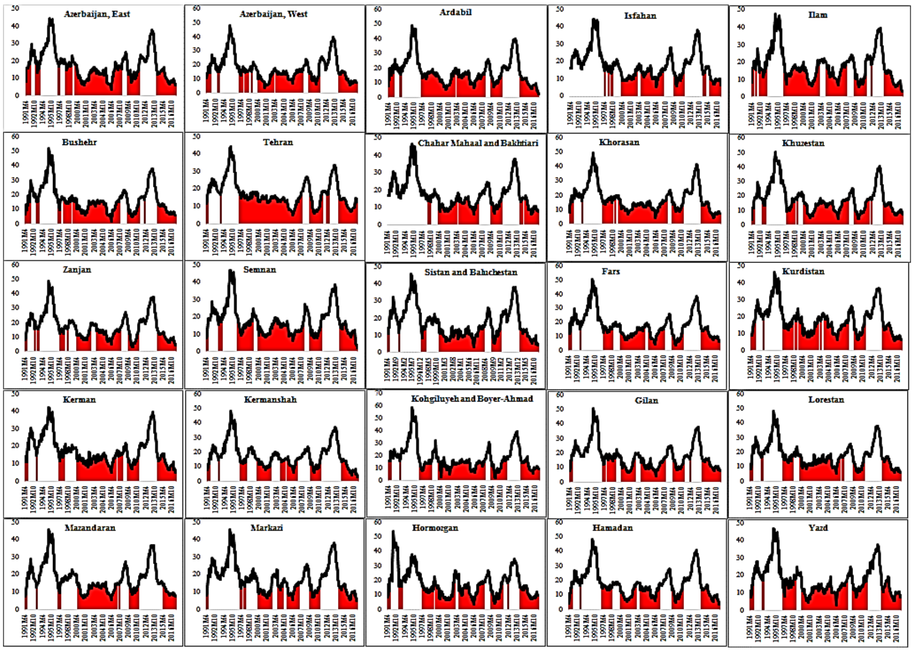

Figure 3: Inflation Rates Dynamics and Mean Reversion Dates

Note: Solid line is the inflation rate, and red shadow is the mean reversion's dates.

5. Conclusion

Iranian economy has experienced high inflation rates over the long period. Hence, one of the main policies is to control for inflation rate. In this paper, there were tested the mean-reversing properties of inflation rates of 25 Iran’s provinces. To the end, there were applied various conventional linear and nonlinear unit root tests, as well as a novel quantile type unit root tests. Using the conventional unit root tests, the null hypothesis of unit root could not be rejected for most of inflation rates series that may be related to non-normal distribution of inflation rate series or a highly degree of persistence of inflation rate series. Results of quantile unit root test that address two aforementioned problems indicate that the inflation rate series of all provinces are globally stationary, but exhibit mean-reverting properties only over quantiles [0.1, 0.5] with half-life between 5–31 months. The positive shock to high quantiles [0.6, 0.9] have permanent effects on the inflation rate series of all provinces. Results for an oil economy such as the Iranian economy suggest that positive shocks arising from oil price boom and injection of oil revenue to economy results in increasing the inflation rate, and according to our results, it is very hard to revert to its steady state level[1]. We suggest that monetary authorities should monitor inflation rise to generate better anchor of inflation expectations, which in turn lead to less persistent inflation. Yet, there is no need to interfere in the market when the inflation rates experience negative shocks. According to the results, the negative shocks disappear in the short-run, and it may not have long-run effects on real economy.

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