Inflation persistence investigation of China based on quantile autoregressive model

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Abstract. It has been noted that high inflation has a significant threat to many countries developments and the persistence of inflation increases the cost of monetary policy in controlling inflation. Therefore, this paper proposes a unique method to estimate inflation persistence by using quantile autoregressive (QAR) model and to show how various shocks may affect the rate of inflation within different quantile levels. Based on the QAR model, the monthly inflation persistence in China and its dynamics over time are considered in the paper. The data illustrated here are the monthly year-on-year Chinese consumer price index from January 1987 to May 2019. The results indicate that the Chinese inflation series is globally stationary, but exhibits non-stationary behavior in about 44.85% of the observations. Again, it is evidence that the Chinese inflation rate has asymmetric characteristics at different quantile levels in its conditional distribution. Our research indicates that the QAR model outperforms the ordinary least square (OLS) method in terms of heterogeneity association of the inflation dynamics.

1. Introduction
High inflation has been a significant threat to many developing countries and the persistence of inflation increases the cost of monetary policy to control inflation. It is well known that inflation persistence has been diminishing over the past decades according to several studies in the literature (e.g., Mishkin, 2007; Stock and Watson, 2007). For instance, there has been a reduction of persistence in the U.S., especially after the 90s, due to the great moderation period. According to Cecchetti et al. (2007), there is also evidence of declining persistence in G7 countries. Therefore, it is very crucial to research the persistence of Inflation.

There have been many types of research on the estimation of inflation persistence in different countries. Among them, the simplest method is to regress inflation by its own lagging order and that is what we call autoregressive (AR) model. After that, the sum of autoregressive coefficients is calculated. The higher the sum, the longer time it takes to recover to the average level after a shock. Roache (2014) stated that a natural way to assess inflation persistence is to verify whether it is stationary (i.e., whether shocks permanently affect the level of inflation or instead fade over time). By pointing out the limitations of the AR model, Koenker and Bassett (1978) proposed quantile regression instead.

The quantile regression technique allows statistical inferences in the entire conditional distribution quantile function, therefore it is widely used in many fields nowadays. In recent years, a great amount of empirical applications appeared in the time-series literature based on quantile regressions, such as: Koenker and Zhao (1996); Engle and Manganelli (2004); Koenker and Xiao (2006); Lima et al. (2008); Xiao (2009); Gaglianone et al. (2011), Gaglianone and Lima (2012, 2014), Xiao (2014), among many others. Regarding the use of quantile autoregressions for analyzing inflation, Çiçek and Akar (2013) for
Turkey and Tillman and Wolters (2014) for the United States are recent examples. In terms of Brazilian inflation, Maia and Cribari Neto (2006) analyzes the dynamics of IPCA and IGP-DI from August/1994 to April/2004. They found that the inflationary dynamics is not uniform across different conditional quantiles. Subsequently, Koenker and Xiao (2006) proposed quantile autoregressive (QAR) model, marking a new stage in the application of quantile regression in the AR model. QAR model can make full use of sample information to describe the real variation of the random variables, which is corresponding to the median and other quantiles.

Enlightened by Koenker and Xiao (2006) this paper focuses on the persistence of China’s inflation based on QAR model. We study the monthly year-on-year Chinese consumer price index (CPI) from January 1987 to May 2019. Our data differ from other researches by using a newest and larger dataset which contains almost 33 years of data.

The results illustrate that the Chinese inflation rate is globally stationary but locally non-stationary which is approximately 44.85% of the sample range. The non-stationary periods are mainly distributed in the upward acceleration stage of inflation, while the stationary periods are mainly distributed in the downward and low inflation stage. In other words, high inflation usually needs more dissipation time to deal with shocks compared to low inflation.

The rest of the paper is organized as follows: Section 2 introduces an overview of the methodology which was used in this paper. Section 3 presents the empirical study and Section 4 provides the conclusion of our study.

2. Methodology
Due to the excellent properties of Quantile Regression (QR) methods, $\tau$ - th quantile of an interpreted variable $y_t$ is expressed as a linear function of its lag variables.

Based on the above ideas, Koenker and Xiao (2002, 2004, 2006) proposed a special QAR model, whose coefficients are dependent on the same random variable $\tau$, and they have function dependency. In order to construct the QAR model, the two necessary assumptions are as follows:

Assumption 1. The random error obeys i.i.d. distribution.

Assumption 2. All of the regression coefficients of the QAR model are independent of the quantile $\tau$.

The p-order autoregression model is defined as follows:

$$y_t = a_0(U_t) + a_1(U_{t-1})y_{t-1} + \cdots + a_p(U_{t-p})y_{t-p}$$

Where the $a_j(U_{t-j})$ are unknown functions which belong to [0, 1] that we need to estimate. Provided that the right part of equation (1) is monotonically increasing with $U_t$, then the $\tau$ - th conditional quantile function of $y_t$ can be written as:

$$Q_{\tau}(y_{t-1}, \cdots, y_{t-p}) = a_0(\tau) + a_1(\tau)y_{t-1} + \cdots + a_p(\tau)y_{t-p}$$

and more compactly as $Q_{\tau}(\tau|F_{t-1}) = x_t^T\alpha(\tau)$, where $x_t^T = (1, y_{t-1}, \cdots, y_{t-p})^T$.

Similar to quantile regression estimation, the estimation of quantile autoregression model can be obtained by solving the problem as follows:

$$\min_{\alpha \in \mathbb{R}^{p+1}} \sum_{t=1}^n \rho_\tau(y_t - x_t^T\alpha)$$

where the $\rho_\tau$ is defined by Koenker and Basset (1978) as follows:

$$\rho_\tau(u) = \begin{cases} \tau u, & u \geq 0 \\ (\tau - 1)u, & u < 0 \end{cases}$$

It is important to note that, compared with mean regression method (e.g. OLS estimation), quantile autoregression method considers a series of quantiles functions under a broader range of conditions to measure conditional heterogeneity, and its estimation is relatively robust.
3. Empirical exercise

3.1. Data

As the data used in most literature, this paper focuses on the monthly year-on-year consumer price index (CPI) in China, which can be used as a measure of monthly inflation. It is worth noting that seasonal factors have been stripped out from the data, so we needn’t adjust the data to avoid some complex dynamic trends in the QAR process.

The sample period ranges from January 1987 to May 2019 consisting of 369 observations. The inflation rate is defined as \( y_t(\%) = CPI(\%) - 100\% \). The original data can be found in the Chinese National Bureau of Statistics (CNBS) website (www.stats.gov.cn).

Figure 1 shows the dynamic trend of the monthly inflation rate since 1987. It can be seen that over the past 30 years, the inflation rate in China changes significantly. Especially before 1997, the general price level of the country fluctuates tremendously severe. It can be evidently seen that the inflation even reached 28.4\% and 27.7\% in February 1989 and October 1994 respectively indicating the two periods with the highest inflation rates. In order to curb high inflation, the Chinese economy has been carrying out the policy of the Soft Landing since 1996. Since the introduction of this policy, the fluctuation of China’s inflation rate has been relatively moderate and the inflation rate has also been significantly reduced.

![Inflation Rate Graph](image)

Table 1 shows some descriptive statistics for the Chinese monthly inflation rate. The results show that, during the whole sample period, the average inflation rate is 5.10\%, and the skewness and kurtosis are 1.90 and 3.00. It shows that the distribution of the inflation rate time series has a high kurtosis, and is obviously skewed to the right.

| Inflation Mean | Median | Maximum | Minimum | Skewness | Kurtosis | Std. Dev. |
|----------------|--------|---------|---------|-----------|----------|-----------|
| %              | 5.10   | 2.50    | 28.40   | -2.20     | 1.90     | 3.00      | 6.75      |

In addition, we use some unit root tests to determine whether the inflation rate series is globally stationary. To make the results more robust, we use Augmented Dickey-Fuller (ADF), Kwiatkowski-Phillips-Schmidt-Shin (KPSS) and Phillips-Perron (PP) unit root tests. The test results are shown in Table 2.
Table 2. Unit root tests.

| Test Method | ADF | KPSS | PP   |
|-------------|-----|------|------|
| P Value     | 0.01| 0.01 | 0.34 |
| Statistical Value | -4.53| 1.94 | -13.70 |
| Critical Value (5%) | -2.87| 0.46 | -2.87 |
| Result (5%)  | Stationary | Non-stationary | Non-stationary |

Notes: The null hypothesis of the KPSS test is stationary, but the null hypothesis of the ADF test and PP test are both non-stationary.

At the significance level of 5%, the KPSS test receives the alternative hypothesis of unit root, and the PP test receives the null hypothesis of unit root, but for the ADF test, the null hypothesis of unit root is rejected. The result of the ADF test shows that the monthly inflation rate is globally stationary. Comparing the accuracy of methods in previous literature, here we use the result of the ADF test, that is to say, the sequence is stationary.

3.2 In-sample analysis

Refer to other kinds of literature on inflation and consider that the impact is getting smaller and smaller over time, so we choose to use the simplest QAR (1) model, as follows:

\[ Q_{y_t}(\tau|y_{t-1}) = \alpha_0(\tau) + \alpha_1(\tau)y_{t-1} \]

First of all, considering \( \tau_{\text{crit}} = 0.55 \) with the quantile separated by 0.1, we can get the regression parameter estimation results of nine autoregression models. The results are shown in Table 3. We observed that the regression parameter estimates of the QAR model are different at different quantiles, indicating that the Chinese inflation rate has asymmetric characteristics at different quantiles in its conditional distribution.

Table 3. Estimated QAR (1) model.

| \( \tau \) | \( \hat{\alpha}_0(\tau) \) | Std. Error | \( \hat{\alpha}_1(\tau) \) | Std. Error |
|--------|-----------------|------------|-----------------|------------|
| 0.10   | -0.57           | 0.10       | 0.92            | 0.03       |
| 0.20   | -0.28           | 0.05       | 0.94            | 0.01       |
| 0.30   | -0.16           | 0.04       | 0.96            | 0.01       |
| 0.40   | -0.08           | 0.04       | 0.98            | 0.01       |
| 0.50   | 0.06            | 0.05       | 0.98            | 0.01       |
| 0.60   | 0.20            | 0.04       | 1.00            | 0.01       |
| 0.70   | 0.23            | 0.03       | 1.03            | 0.01       |
| 0.80   | 0.38            | 0.06       | 1.05            | 0.01       |
| 0.90   | 0.62            | 0.10       | 1.07            | 0.02       |

Next, we make finer segmentation of the quantile (\( \tau \in [0.01,0.99] \)) which is separated by 0.01. The intercept and regression coefficient estimates of OLS and QAR methods are compared in Figure 2.
The solid line and two dashed lines in Figure 2 show the estimated intercept and regression coefficients of OLS and their 95% confidence intervals respectively. The dotted line and the shaded part show the estimated intercept and regression coefficients of QAR (1) and their 95% confidence intervals at $\tau \in [0.01, 0.99]$ by steps of 0.01 respectively. We can find that QAR model is indeed better than simple OLS estimates.

The QAR (1) model was constructed under $\tau_{crit}=0.55$. According to this model, we can get the predicted value $\hat{Q}_{yt}(\tau_{crit}|y_{t-1})$ by predicting the time series, and compare with the true value $y_t$ to find out the non-stationary periods. We can judge non-stationary periods by using the indicator variable $I_t = \begin{cases} 1, & \text{if } y_t > \hat{Q}_{yt}(\tau_{crit}=0.55)|y_{t-1}) \\ 0, & \text{otherwise} \end{cases}$

Figure 3 shows the time-varying characteristics of the Chinese inflation rate. The black line represents the time series graph of the inflation rate. The grey areas indicate that the inflation rate is non-stationary at that moment, while the white areas show that the inflation rate is stationary during these periods. As can be seen from the density of the grey vertical lines in the figure, the two states of Chinese inflation have the characteristics of centralized distribution and the number of stationary periods is obviously more than that of non-stationary periods which can also be seen that about 44.85% of the
whole sample periods are non-stationary. The results prove that the Chinese inflation rate is locally non-stationary but globally stationary.

Figure 4. The Twelve-month accumulated number of non-stationary periods.

Figure 4 shows the annual cumulative frequency of non-stationary periods of Chinese inflation during the sample interval, which further proves the time-varying characteristics of the Chinese inflation rate. The two dotted lines represent 3 and 9 periods, and one bold line representing 6 periods of the non-stationary behavior.

4. Conclusions
Based on the historical materials and the dynamic characteristics of Chinese inflation, the paper studies the persistence of inflation rate in China by using QAR model and quantile unit root test methods, analyzes the asymmetric characteristics of the changing process of inflation rate, and finally comes to the following conclusions.

(1) The QAR model is superior to OLS estimation. When the intercept terms and regression coefficients of OLS estimation and QAR model are compared respectively, we find that the QAR model can better reflect the dynamic process of inflation series.

(2) Chinese inflation rate has high persistence characteristics. Both in the middle and the end of the conditional distribution of inflation, the inflation persistence coefficient which is calculated based on QAR model is very close to 1.

(3) The persistence of Chinese inflation has asymmetric dynamic characteristics. The results show that the inflation has a higher persistence when at a higher quantile in the inflation conditional distribution, but a lower persistence when the quantile is lower.

(4) In the long run, Chinese inflation persistence has the characteristics of time-varying. Under the condition of accelerating inflation, the inflation series mainly obeys the unit root process. But in the stage of falling or low inflation, the inflation rate series mainly obeys the stationary autoregression process.

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References
[1] Anguyo, F. L., Gupta, R., & Kotzé, K. (2017). Inflation Dynamics in Uganda: A Quantile Regression Approach (No. 201772).
[2] Cai, Y. (2010). Forecasting for quantile self-exciting threshold autoregressive time series models. Biometrika, 97(1), 199-208.
[3] Cecchetti, S., Hooper, P., Kasman, B., Schoenhols, K., Watson, M., 2007. Understanding the Evolving Inflation Process U.S. Monetary Policy Forum Report No. 1. Rosenberg Institute for Global Finance, Brandeis International Business School and Initiative on Global Financial Markets, University of Chicago Graduate School of Business.

[4] Gaglianone, W. P., de Carvalho Guillén, O. T., & Figueiredo, F. M. R. (2018). Estimating inflation persistence by quantile autoregression with quantile-specific unit roots. Economic Modelling, 73, 407-430.

[5] Gaglianone, W., Guillén, O., & Figueiredo, F. (2015). Local Unit Root and Inflationary Inertia in Brazil. Documento de Trabajo del Banco Central de Brasil, (406).

[6] IMF, International Monetary Fund, 2017. World Economic Outlook: Seeking Sustainable Growth - Short-term Recovery, Long-term Challenges.

[7] Knight, K., 1989. Limit Theory for Autoregressive-Parameter Estimates in an Infinite-Variance Random Walk. Canadian Journal of Statistics, 17(3), 261-278.

[8] Koenker, R., 2005. Quantile Regression. Cambridge University Press, Cambridge, UK.

[9] Koenker, R., Bassett, G., 1978. Regression quantiles. Econometrica 46, 33–49.

[10] Koenker, R., Machado, J.A.F., 1999. The goodness of fit and related inference processes for quantile regression. J. Am. Stat. Assoc. 94 (448), 1296–1310.

[11] Koenker, R., Xiao, Z., 2002. Inference on the quantile regression process. Econometrica70, 1583–1612.

[12] Koenker, R., Xiao, Z., 2004. Unit root quantile autoregression inference. J. Am. Stat. Assoc. 99, 775–787.

[13] Koenker, R., Xiao, Z., 2006. Quantile autoregression. J. Am. Stat. Assoc., 101(475), 980–990.

[14] Koul, H.L., 1994. Mukherjee, K. Regression quantiles and related processes under long-range dependent errors. Journal of multivariate analysis, 51(2), 318-337.

[15] Lima, L.R., Gaglianone, W.P., Sampaio, R.M.B., 2008. The debt ceiling and fiscal sustainability in Brazil: a quantile autoregression approach. J. Dev. Econ. 86 (2), 313–335.

[16] Mishkin, F., 2007. Inflation dynamics. Int. Finance 10 (3), 317–334.

[17] Roache, S., 2014. Inflation Persistence in Brazil - a Cross Country Comparison. IMF Working Paper, No.55.