Asymmetric response of Brazilian inflation: evidence based on weekly data, 2003-2017

André M. Marques*

May 4, 2018

This study analyzes the nature of weekly inflation response to shocks in the Brazilian economy by adopting a quantile autoregression model in which the autoregressive parameter (α) is allowed to be quantile dependent. We test for unit root at different quantiles of the response variable, by characterizing its asymmetric dynamics along the business cycle. In addition, we evaluate the robustness of the results by adopting a bootstrap procedure. We find strong evidence of asymmetric persistence in inflationary dynamics, in which an inflationary impulse below the average dissipates very fast when compared to an inflationary impulse occurring above the average. Hence, the location, size and sign of a random shock matter for monetary policy. The full inertia hypothesis is supported only at upper tail of the conditional distribution.

Keywords: Inflation; Local persistence; Asymmetric dynamics; Quantile Regression; Bootstrap.

Este estudo analisa a resposta a choques da inflação semanal no Brasil através de um modelo de auto-regressão quantílica, em que o parâmetro autorregressivo (α) é dependente do quantil. A hipótese de raiz unitária é testada em diferentes quantis da variável resposta, permitindo a ocorrência de dinâmica assimétrica ao longo do ciclo de negócios. A robustez dos resultados foi avaliada por um procedimento de bootstrap. Há evidências de assimetria na persistência inflacionária, em que um choque abaixo da média tem efeito temporário e choques acima da média tem efeito permanente. A localização, o tamanho e o sinal de um choque aleatório importam para a política monetária. A hipótese de inércia plena é corroborada apenas na cauda superior da distribuição condicional.

Palavras-chave: Inflação; Persistência local; Dinâmica Assimétrica; Regressão Quantílica; Bootstrap.
JEL Classification: C14; C22; C13.
Área Anpec: 04 - Teoria Econômica e Métodos Quantitativos.

*Doctor of Economics. I am very grateful to Vinicius Aguiar de Souza and Guilherme de Oliveira who made countless suggestions and corrections into the first draft. Additionally, I would like to thank André Roncaglia de Carvalho and Joelson Oliveira Sampaio who kindly help me with the data used in this paper. All remaining errors are mine. *Correspondence*: Federal University of Paraíba, Department of Economics, Cidade Universitária, s/n, Castelo Branco, 58051-900, João Pessoa, Brazil. Phone: (+55) 83 3216 7453. E-mail: `00094751@ufrgs.br`

1 Introduction

The generalized adoption of Inflation Targeting Regime (ITR) in developed and emerging market economies assumes that policymakers can reduce inflation by reducing the level of output. The response of inflation to the output loss depends upon the degree of inflation persistence and its entire dynamics along the business cycle. If the inflation persistence is relatively low, the output costs to reduce inflation will be relatively small.

A common source of external inflationary shock has been the currency crises experienced by emergent market economies. As pointed out by Granger et. al. (2000), the currency crisis which began in Thailand in July 1997 has spread across several Asian countries. The South Korea, Malaysia, Taiwan, Philippines and Indonesia set off severe pressures in the stock markets in the third quarter of 1997, and a number of other Asian countries also experienced substantial depreciation of their currencies. [1]

The currency crises can be interpreted as a source of (inflationary) external shocks into the domestic inflation rate because the exchange rate depreciation affects the internal prices. That was the case of Brazil in 2002, when the economy faced a negative swing of US 30 billion in capital flows (6% of its gross domestic product - GDP), leading to a nominal depreciation of 50% in the exchange rate.

Another well known example in Brazil refers to the mid-January 1999, when the currency devaluation emerged as a shock that forced a realignment of relative prices. The inflation rose sharply: the wholesale price index increased 3.2% and the consumer price index raised 1.29% in February.

The output loss in the following periods caused by that external driver depends upon how long a random shock perpetuates upon future rising prices, since in an environment of ITR it implies a higher interest rate policy in the future periods. The duration of these random shocks is measured by the inflation persistence, an important feature of the price inflation.

The effect of an inflationary shock may have permanent effects over future prices. As pointed out by Busato et al. (2009), if there is evidence of full inertia ($\alpha = 1$) the economy may experience a permanently higher inflation rate, a strong hypothesis which has received little support in the literature and is consistent with the *New Consensus Economics*.

In contrast with currency crises, considering the fact that product or process innovations are the main driver of productivity factor enhancement in the manufacturing industry, the trade liberalization in Brazil at the early 1990's can be interpreted as a major source of a (deflationary) positive supply shock (Lopes, 1985; Franco, 1998; Hayakawa and Matsuura, 2017).

If a deflationary supply shock can cause a *permanent* reduction in level of inflation rate, the operation of the Inflation Targeting Regime by the Central Bank is facilitated, thus contributing to attenuate the inflationary process.

However, as observed by Lopes (1985), nothing guarantees this kind of postulated symmetric persistence behavior in the inflation level. If an external or a domestic fiscal inflationary shock produces a permanent effect, and a supply deflationary shock does not, the focus of policymakers and their response to monetary policy issues must be limited to the former. Shocks occurring below the average may have transitory effects, and shocks above the average may produce permanent effects over the inflation rate.

The main objective of the present study is to analyze the nature of local persistence in the Brazilian weekly inflation rate to test whether it exhibits symmetric behavior in relation to shocks along business cycle by using a Quantile Autoregression Model. We consider a case where a ran-

[1] The Rupiah of Indonesia suffered the greatest depreciation in its value (144.83%) against the US dollar, and in the other affected Asian countries that figure situated around 50%. See Granger et. al. (2000).

dom shock can change the location, scale and shape of the entire conditional inflation distribution and not only to the average inflation rate.

The existing empirical literature that analyze the inflation persistence in Brazil generally employs constant-coefficient time series models which concentrates only at the conditional mean of the response variable, also supposing that the persistence parameter is independent of its quantiles. As observed by Fraga et al. (2003, p. 389), the optimal response of monetary authorities may depend upon the nature and size of the shock that hits the economy.

In addition, according to the inertial inflation hypothesis, the degree of persistence depends upon the level of inflation. Resende (1985b, p. 130) observes that high inflation requires indexation, and indexation prevents the reduction of inflation. Both theoretical assertions cannot be tested by a constant-coefficient linear times series model based only upon conditional mean regression methods.[2]

In contrast, the Quantile Autoregression (QAR) model can be viewed as a case of random-coefficients time series model in which the autoregressive coefficient is dependent of the specified quantile, $\tau \in [0,1]$. Thus, it can be used to describe the entire conditional distribution of a response variable providing a more complete picture of its dynamics. The level of inflation can be associated with to the degree of indexation.

One of the contributions of the present study is to test the unit root hypothesis not only at the conditional mean of the inflation path, but also at the tails of the distribution. Hence, we can distinguish between response to shocks when the inflation realizations is high or low in relation to previous periods.

In addition, most of the studies use only monthly dataset since it is difficult to collect data and compute inflation index at higher frequency. When compared to the existing works, the preset study contributes to this empirical literature by using a higher frequency dataset - the weekly inflation index - which means more information. As we increase the sample size, we can get more precise estimators and test statistics with more power.

The QAR model also allows for the possibility that shocks of different signs and magnitudes have an asymmetric impact on inflation path. This method is not restricted to a fixed number of regimes, but it accounts for differences in the transmission of all kinds of shocks. This is particularly important in Brazilian economy because some studies indicate that the majority of private firms adjust prices using state-dependent practices, but some of them also consider elements of time dependency, particularly in services sector (Correa et al., 2016).

Beyond that, the unit root test based on quantile regression presents higher power than conventional unit root tests as shown by simulation studies (see Koenker and Xiao (2004)). Besides, the QAR based unit root test is superior to standard unit root tests in case of departure from normal distribution of residuals.

The main findings of the present paper does not support the hypothesis of symmetric response to economic shocks. Further, it seems that the degree of indexation depends upon the level of inflation, as suggested by the theoretical models designed to describe the inertial inflation in Brazil, like Lopes (1985), Arida (1985) and Simonsen (1985). In general, inflationary shocks occurring above the average have permanent effects on its level, while deflationary shocks occurring below the average produce transitory effects on the inflation level. The results are corroborated by an additional robustness analysis based on wild bootstrap procedure. The full inertia hypothesis is supported only for above than average inflation realizations.

The remainder of the paper is organized as follows: Section 2 briefly reviews the main works seeking to measure inflation persistence in Brazil and discuss its main findings. Section 3 outlines the methodology and describes the data. Section 4 presents the results and discusses the main

[2] Lopes (1985) shows that the generalized behavior of indexation is compatible with the postulate of rationality. See also Arida and Resende (1984).

findings, while Section 5 concludes the paper.

2 Inflation Persistence in Brazil

Quantile unit root test have been used to analyze and describe asymmetric persistence behavior as a viable alternative to conditional mean regression models. Hosseinkouchack and Wolters (2013) apply the unit root test in quantiles to test whether financial crisis produced a permanent or a transitory effect on US GDP. Lima et al. (2008) investigate fiscal sustainability by using QAR model with Brazilian data. Their methodology allow to separate periods of nonstationarity from stationary ones to identify various trajectories of public debt that are compatible with fiscal sustainability.

Koenker and Xiao (2006) apply the quantile autoregression model to analyze whether the response of US unemployment rate and weekly gasoline price to expansionary or contractionary shocks may be asymmetric. Viola et al. (2017) employ the conditional autoregressive value at risk (CAViaR) model introduced by Engle and Manganelli (2004) to predict the exchange rate volatility in Brazil allowing for asymmetric dynamics in the returns distribution. In the present study we are interested in the autoregressive coefficient α estimated for each specified quantile, as a measure of inflation response to shocks.

The inflation persistence in Brazil has been a major issue in economic policy since the implementation of ITR in mid 1999 and even before.[3] Early theoretical works on inertial inflation, especially Lopes (1985), Arida (1985), Resende (1985) and Simonsen (1985) emphasized the need to abolish the indexation of wages, prices and other forms of state induced rules for price setting that are independent of supply and demand. Dornbusch et al. (1990) examine the same theoretical and empirical issues of indexation and hyperinflation problems in a large of number of countries, including Brazil. The policy prescriptions derived by the authors are all in line with early theorists of inertial inflation hypothesis.

But, even after decades of hyperinflation and difficulties to reach a low and stable inflation based on Real Plan at 1994, the government still maintains many mechanisms to stimulate indexation rules in the Brazilian economy. All these formal and informal rules contribute to increase inflation persistence, resulting in a relatively great output loss that follows a given economic disturbance.[4]

The inflation persistence and its drivers present another challenge to the operation of ITR by the Central Bank. Fraga et al. (2003) points out that the control over inflation path in Brazil is difficult because it exhibits imperfect credibility that pervades its institutions and the high degree of inflation persistence derived from state induced rules of indexation (formal and informal) in price setting.

As referred to Bogdanski et al. (2000) and Fraga et al. (2003), the Brazilian inflation persistence may depend on a series of state regulated prices like indexed wage contracts, public transport fare, gasoline, diesel oil, electricity, telephone and post office rates, education, health plan rates and a lot of other prices (see Figueiredo and Ferreira, 2002, p. 6). These goods and services have their pricing rules based on contractual law which is unrelated to supply and demand conditions. Additionally, the government is the major supplier of these goods and services.

Besides, in the private sector, the results presented by Correa et al. (2016) indicate that the majority firms in Brazil adjust their prices according to a monopolistic competitive model in an almost closed economy, where markup pricing is the dominant price setting strategy. Another important element is the price of competitors: around 67% of firms in private sector consider crucial to change prices only after knowing about how competitors have readjusted their price.

[3]For a detailed description of Inflation Targeting Regime in Brazil, see Bogdanski et al. (2000).

[4]For a detailed account of Real Plan, see Bacha (1997).

The main drivers of price changes are the costs of intermediate goods and the inflation rate.

Some studies have been conducted to analyze the inflation persistence in the Brazilian economy, most of them by using monthly dataset for several periods. Some studies reported a reduction in inflation persistence after the Real Plan even when most of the works employed conditional mean regression methods.

Campelo and Cribari-Neto (2003) analyze the Brazilian inflation persistence for both the same inflation index used by Cati et al. (1999) and for IGP-DI (Índice Geral de Preços - Disponibilidade Interna) computed by the Getulio Vargas Foundation. They estimate that the inflation persistence for the corresponding series are 0.10 and 0.17. These values are considerably smaller than the ones reported by Cati et al. (1999). The authors found a low degree of inflation inertia regardless of the persistence measure or the dataset used, which contrasted with the conclusions raised by Cati et al. (1999).

Minella et al. (2002) also find some evidence of change in inflation rate dynamics. Their results suggest that after ITR, the inflation persistence dropped from 0.81 to 0.23. This last coefficient is similar to that found by Campelo and Cribari-Neto (2003). Minella et al. (2002) concluded that there has been a substantial reduction in the degree of inflation persistence after ITR. This implies a lower output loss to reduce average inflation.

Figueiredo and Marques (2009) analyze several subsamples of the Brazilian monthly inflation rate. The authors apply the unit root test introduced by Zivot and Andrews (1992) allowing for structural change in an unknown date. They concluded that shocks have a transitory effect on the inflation path when analyzing the monthly data ranging from 1994 to 2008 (IGP-DI index). The fractional coefficient is 0.25 which indicates that after the Real Plan, the Brazilian inflation faced a lower persistence and can be considered stationary.

Furthermore, Figueiredo and Marques (2011) employ a model which accounts for regime switching and estimates the fractional coefficient to the Brazilian inflation using a monthly dataset ranging from 1944 to 2009 (IGP-DI index). They concluded that the inflation rate can be considered stationary after the Real Plan.

To the best of our knowledge, Maia and Cribari-Neto (2006) are the only authors who apply similar methods to the ones used here for (lower frequency) monthly Brazilian inflation rate. They employ the QAR model to test for unit root in a range of quantiles using monthly data ranging from 1994 to 2004. The dataset used in that work were the IGP-DI index computed by Fundação Getúlio Vargas and the IPCA (Índice de Preços ao Consumidor Amplo) computed by the Instituto Brasileiro de Geografa e Estatística (IBGE).

Their findings indicate an asymmetric behavior in inflation persistence, supporting the hypothesis of unit root in Brazilian inflation rate only for IPCA index at quantiles $\tau = [0.85; 0.90]$. The authors were able to reject the null hypothesis of infinite persistence in all other quantiles in both price indexes. This result indicates that the inflation persistence may depend on the location of the response variable. In comparison with the present study, the main limitations of their work are both the lower frequency data used in the paper and the absence of some robustness analysis.

The present study applies the methods developed by Koenker and Xiao (2004; 2006). The dataset used here is considerably larger when compared to the earlier studies because we use higher frequency (weekly) data. Additionally, we perform a robustness analysis through bootstrap techniques designed specially for QAR methods. Using these additional procedures and dataset, we hope to find more robust and reliable conclusions then previous studies.

Table 1: Descriptive statistics for the weekly inflation rate (%): Feb, 06, 2003 to Mar,31, 2017.

Descriptive statistics	
Mean	0.52
1^{o} Quartile	0.28
Median	0.49
3^{o} Quartile	0.73
Minimum	-0.44
Maximum	2.16
Skewness	0.48
Kurtosis	4.18
Jarque-Bera test	66.57*
Shapiro-Wilk test	0.98*

(*) Significant at 1% level.

3 Methodology

3.1 Description of the Data

The data used in this study is the IPCS (Índice de preços ao consumidor semanal, %) computed by the Fundação Getúlio Vargas ranging from February, 06, 2003 to March, 31, 2017, corresponding to 15 years of weekly observations ($T = 688$). The Table 1 presents the descriptive statistics.

The data presents positive skewness indicating that most of the time the inflation rate stood above the average of the sample. The kurtosis and statistical tests for normality indicate that the data does not fit a normal distribution. We are able to reject the null of the normal distribution in both Jarque-Bera and Shapiro-Wilk tests at 0.01 probability level.

The positive skewness and departure from normality highlight the virtue of QAR modeling approach, which is robust for these data characteristics and may better describe the changes in conditional distribution of the response variable.

Figure 1 shows the path of Brazilian inflation along the years and its estimated trend obtained by the HP filter with and without drift. We can observe higher *peaks* between 2014 and 2016 associated with the more recent effects of political crisis, the pervasive corruption in the country, beyond that price suppression (e.g., energy prices), regime change, monetary and fiscal policy decisions (such as the abandonment of the fiscal surplus target as a percentage of the GDP). In spite of a trend apparently absent, a restricted version of Eq. 2 without it was rejected at 0.10 probability level (F-statistic = 3.4; p-value = 0.0657) by adopting $q = 29$. Hence, we adopted the full specification given in Eq. (2) in all estimated models.

3.2 The Quantile Autoregression Model

Let y_t be the weekly inflation rate level and ε_t an uncorrelated error term. An AR(q) process for the weekly inflation is given by:

$$y_t = \mu + \beta t + \sum_{i=1}^{q} \gamma_i y_{t-i} + \varepsilon_t, t = q+1, q+2, \ldots, T. \tag{1}$$

The inflation persistence is measured by the sum $\sum_{i=1}^{q} \gamma_i y_{t-i} = \alpha$. This magnitude is the main focus of this work, since it is the first measure of persistence and it can be used for posterior analysis, e.g., the impulse response functions and half-live computations (Andrews, 1993).

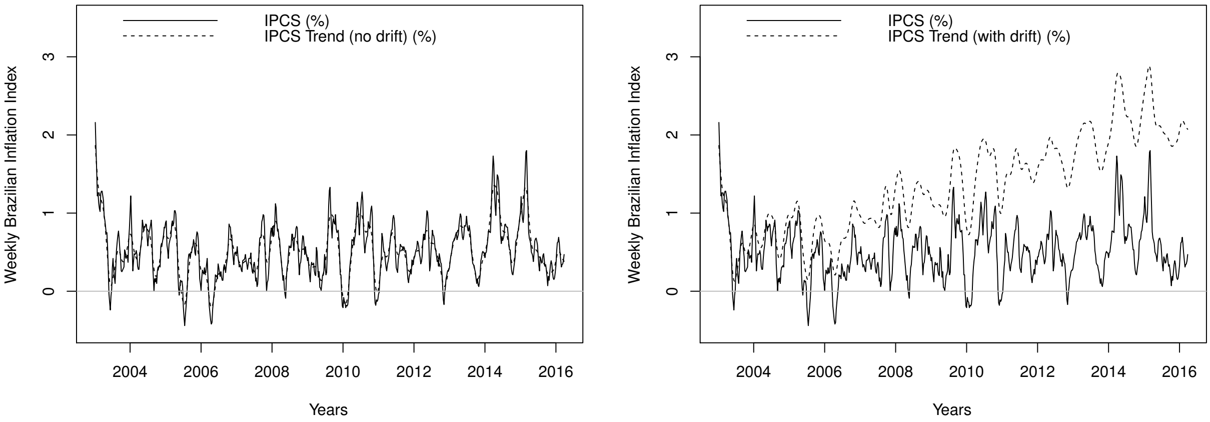

Figure 1: IPCS (%), 2003-2017. Weekly data.

Equation 1 can be rewritten as,

$$y_t = \alpha y_{t-1} + \mu + \beta t + \sum_{i=1}^{q-1} \phi_i \Delta y_{t-i} + \varepsilon_t. \tag{2}$$

Based on Eq. (2) the usual methods can be used to test the following hypothesis: if $\alpha = 1$, the random shock causes permanent effects, otherwise if $\alpha < 1$, the random shock causes temporary effects. The limitation of this approach is that it assumes that the persistence parameter α is independent of the quantile $\tau \in [0,1]$ of the conditional distribution of the response variable.

For better understanding of the inflationary process and the nature of its persistence along the business cycle we need to go beyond the conditional mean of the dependent variable and to estimate the persistence parameter α at the tails of the conditional distribution.

The τ-th conditional quantile is defined as the value of $Q_\tau(y_t|y_{t-1},\ldots,y_{t-q})$ such that the probability that inflation rate conditional on its lagged values will be less than $Q_\tau(y_t|y_{t-1},\ldots,y_{t-q})$ is τ. The QAR(q) process at quantile τ for the inflation rate can be expressed by,

$$Q_\tau(y_t|y_{t-1},\ldots,y_{t-q}) = \alpha(\tau)y_{t-1} + \mu(\tau) + \beta t + \sum_{i=1}^{q-1} \phi_i(\tau)\Delta y_{t-i} + \varepsilon_t. \tag{3}$$

The estimation method used in the present empirical strategy is the same introduced by Koenker and Basset (1978), which is based on the quantile loss function and still have been applied in this modeling approach (Koenker and Xiao, 2006). We can test the hypothesis $\alpha = 1$ at different values of τ, accounting for negative and positive shocks of different magnitudes. We test the unit root hypothesis by the method introduced by Koenker and Xiao (2004) which was extended by Galvao (2009) to include deterministic components.

Let $\hat{\alpha}(\tau)$ be the quantile regression estimator. To test the null $\alpha = 1$ we adopt the t-statistic for $\hat{\alpha}(\tau)$ proposed by Koenker and Xiao (2004), expressed as:

$$t_n(\tau) = \frac{f\left(\widehat{F^{-1}(\tau)}\right)}{\sqrt{\tau(1-\tau)}}(Y'_{-1}M_Z Y_{-1})^{1/2}(\hat{\alpha}(\tau) - 1), \tag{4}$$

in which $f(\cdot)$ and $F(\cdot)$ are the probability and cumulative density functions of ε_t, Y_{-1} is the vector of lagged inflation index and M_Z is projection matrix onto the orthogonal to $Z = (1, t, \Delta y_{t-1}, \ldots, \Delta y_{t-q+1})$.

We apply the theoretical results derived by Koenker and Xiao (2004) and Galvao (2009) to simulate the critical values of $t_n(\tau)$-statistic for the same quantile levels used by Maia and Cribari-Neto (2006). We performed $R = 10000$ replications to get the results[5] presented in Table 3.

The estimate of Eq.(3) deliveries the persistence measure $\alpha(\tau)$ over different quantiles of the conditional distribution, $\tau \in [0,1]$. Following Andrews (1993), we calculate the length of time until the impulse response function of a unit shock to inflation rate is equal to half of its original magnitude - the half-life of a unit shock. This number characterizes (in weeks) the likely duration of inflation in response to shocks in each specified quantile and is defined by

$$HL(\hat{\alpha}) := \frac{\log(1/2)}{\log(\hat{\alpha})}, \tag{5}$$

along with the impulse response function (*IRF*) defined by,

$$IRF(\hat{\alpha}) := \hat{\alpha}^t, \forall t = 0, 1, 2, \ldots \tag{6}$$

which also can be found in Andrews (1993). The magnitude of the *(IRF)* across different time horizons according to the value of t in weeks gives an indication of the extent of the persistence of shocks to the inflation level. By following the intuitive interpretation given in Taylor and Taylor (2004), we can say that inflation rate reverts towards its mean (or conditional quantile) at the rate of $(1 - \hat{\alpha})$ per period.

Since the data used in this study was collected at a higher frequency, we adopt a bootstrap procedure designed to QAR methods introduced by Feng et al. (2011). This procedure works as a check the robustness of the results against fat tailed or GARCH-type effects (or both) on the estimator efficiency.

Baur et al. (2012) conducted a Monte Carlo study to verify the effects of these time series properties on quantile autoregression. The authors conclude that the simulation results revealed no deviations from the simulated autoregressive parameter across the entire range of quantiles. Hence, we hope to find more efficient estimates to the coefficient α at specified quantiles, $\tau \in [0;1]$.

We adopt the wild bootstrap procedures proposed by Feng et al. (2011), as described in the following steps:

1. Estimate Eq. (3) to the data, and denote the estimate of the parameter vector by $\hat{\beta}$ and use $\hat{\varepsilon}_i$, to define the residuals $(i = 1, \ldots, n)$.
2. Generate the weights ω_i from an appropriate distribution and let $\hat{\varepsilon_i^*} = \omega_i |\hat{\varepsilon}_i|$.
3. Calculate the bootstrap sample $y_i^* = x_i^T \hat{\beta} + \hat{\varepsilon_i^*}$.
4. Reestimate Eq.(3) from the bootstrapped sample and denote the bootstrap estimate by $\hat{\beta}^*$.
5. Repeat the steps 2 to 4, a large number of times R, and estimate the variance of $\hat{\beta}$ by the sample variance of the R copies of $\hat{\beta}^*$.

4 Results and Discussion

4.1 General Results of the QAR Model

At first, to verify whether the inflation rate may be considered as a globally stationary process we applied three unit root tests to the level of the series. The results to the tests ADF (MAIC) - Dickey and Fuller (1979), KPSS (1992) and Zivot & Andrews (1992) to allow structural change at unknown date are shown in Table 2.

[5]Routines are available to the author under request.

Table 2: Tests for stationarity of the weekly inflation rate (%)

Type of the test	*Constant*	*Constant and trend*
ADF (MAIC)	-5.63*	-5.82*
KPSS	0.22	0.10
Zivot & Andrews	-7.92*	-8.23*

(*) Significant at 1% level.

Table 3: Null hypothesis: $\alpha(\tau) = 1$ for $\tau \in [0.05; 0.95]$ - Weekly inflation.

τ	$\hat{\alpha}(\tau)$	*t-statistics*	*critical values*
0.05	0.7979	-4.3570**	-2.7478
0.10	0.8324	-4.4514**	-2.7247
0.15	0.8229	-5.7784**	-2.8768
0.20	0.8430	-4.9459**	-2.8784
0.25	0.8475	-4.9118**	-2.9437
0.30	0.8797	-3.9123**	-3.0229
0.35	0.8798	-3.7728**	-3.0921
0.40	0.8628	-4.4717**	-3.1258
0.45	0.8833	-3.9923**	-3.1185
0.50	0.8804	-4.2526**	-3.1060
0.55	0.8907	-4.0221**	-3.1183
0.60	0.9156	-2.9824	-3.0311
0.65	0.9282	-2.3522	-3.1055
0.70	0.9355	-2.0161	-3.0415
0.75	0.9450	-1.7196	-2.9792
0.80	0.9756	-0.7435	-2.7941
0.85	0.9711	-0.8096	-2.8720
0.90	0.9558	-0.8953	-2.7110
0.95	1.0144	0.2016	-2.3813

(**) Significant at 5% level.

All the three tests corroborate the low degree of inflation persistence in the Brazilian economy by considering only its conditional mean. These results are consistent with the conclusions presented in the section 2: the Brazilian inflation rate can be considered stationary by methods designed to account only its conditional mean. We are able to reject the null of unit root at 0.05 and 0.01 probability levels.

The estimated date of structural change is October, 15, 2014. This may suggest that the underlying economic process are subject to an abrupt change or was recently hit by a shock in Brazilian economy. The dummy coefficients are all significants at 0.01 probability level.

The Table 3 presents the results for unit root test using the QAR model given by Eq.(3), based on 10000 replications. We choose the lag length based on MAIC criterion recommended by Ng and Perron (2001). We find the best lag length of $q = 29$ and apply this for all considered quantiles τ.

The above results allow to draw the following main conclusions. First, at the upper tail of the distribution, we are unable to reject the unit root hypothesis at a broader range of quantiles (from $\tau = 0.60$ to $\tau = 0.95$). And, at the lower tail of the distribution and at the average, we are able to reject the null at 0.05 probability level in all quantiles. At the quantile $\tau = 0.60$ we observe a borderline non-rejection of the null at 0.05 probability level, since both t-statistic and critical value are very proximate.

Second, in relation to the previous results of Maia and Cribari-Neto (2006) for monthly inflation rate, the noticeable difference is that we are unable to reject the null at a broader range of quantiles. The difference in these findings may be attributed to different frequency of the dataset used and to the range of observations. It is well known that lower frequency data presents less information and smoother behavior when compared to higher frequency data.

These findings imply a stronger asymmetric response than the previous results would suggest: an inflationary shock near (above) the average now can result in a permanent effect over future rising prices.

This new result hidden in monthly inflation indexes indicates that some policy monetary decisions maybe gain fine tunning by using data of higher frequency, like price index or other indicators of economic activity in Brazil.

In addition, if we compare these findings with those works based on conditional mean regression models, we may conclude that there is no substantial difference. In the conditional mean, the Brazilian inflation path can be considered stationary. However, the novelty is that in the *peaks* of business cycle shown in Figure 1 a demand or an external shock may produce a permanent effect on future rising prices.

Meanwhile, with conditional mean regression models the asymmetric dynamic of the inflation path would not be revealed. Hence, the above findings adds new information on the inflation persistence literature and partially corroborates previous results for monthly data (based on IPCA index only).

Summing up, the average regression (dashed line) in the Figure 2 below masks the increasing degree of inflation response to shocks along of 19 quantiles, $\tau = [0.05; 0.95]$. It is noticeable that in spite of the occurrence a large recession since 2014, the aggregated prices indexes present a delayed reduction when compared to capacity utilization and the free fall in employment of labor.

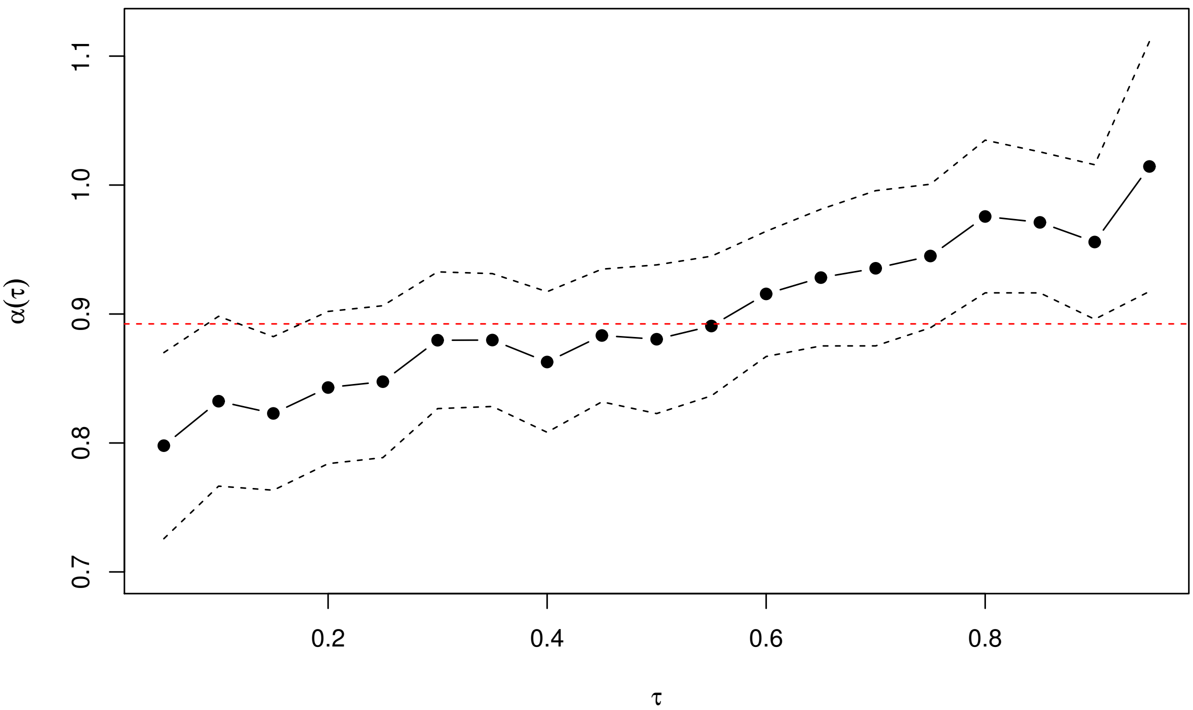

Figure 2: AR(1) coefficient with 95% Bootstrap Confidence Interval.

Table 4: Estimates for $\alpha(\tau)$ in a smaller range of quantiles, $\tau \in [0.05; 0.95]$

τ	$\hat{\alpha}(\tau)$	95% *bootstrap CI*	*HL* in weeks	*IRF* ($t = 8$)	*IRF* ($t = 16$)
0.05	0.7979	[0.724;0.872]	3.1	0.1643	0.0270
0.10	0.8324	[0.768;0.897]	3.8	0.2304	0.0531
0.25	0.8475	[0.784;0.911]	4.2	0.2662	0.0709
0.40	0.8628	[0.810;0.916]	4.7	0.3071	0.0943
0.50	0.8804	[0.827;0.934]	5.4	0.3611	0.1304
0.60	0.9156	[0.867;0.964]	7.9	0.4939	0.2439
0.75	0.9450	[0.890;1.000]	12.3	0.6359	0.4044
0.80	0.9756	[0.913;1.038]	∞	0.8208	0.6737
0.90	0.9558	[0.888;1.023]	∞	0.6967	0.4854
0.95	1.0144	[0.906;1.123]	∞	1.1213	1.2572

4.2 Robustness Analysis

We estimate the Eq.(3) and apply the bootstrap procedures described above. The lag length used in the estimations is the same used before, $q = 29$, and the number of bootstrap replications used was also 10000. We consider a smaller range of quantiles in order to compare these results to the previous findings. The confidence interval adopted is defined as $\hat{\alpha} \pm 1.96 * se_{boot}$ because the number of degrees of freedom is above 20 and the significance level is set at 0.05.

Based on the comparison between the Tables 3 and 4 we can conclude that the two methods deliver similar results. In relation to the borderline non-rejection of unit root at quantile $\tau = 0.60$ by the first method, now we can safely reject the unit root based on bootstrap estimates at 0.05 probability level.

If we consider the median of distribution, as the value of the coefficient which is distant from unit, we may consider that weekly inflation rate is stationary in average. This conclusion is consistent with the evidence reported by the related literature.

However, if we consider the duration of an inflationary shock above the average, to return to half of its initial level it requires a long time span in some cases, or, it approaches to infinity at the extreme quantiles. The speed of price adjustment spans from 3 to 5 weeks below the average, but above the average such a magnitude grows relatively fast and translates into a permanent rising prices.

5 Conclusions

The main objective of this study was to test the unit root hypothesis along its entire conditional distribution of the Brazilian inflation level. By applying the QAR model along with a higher frequency dataset - the weekly inflation rate index - we found new results when compared to the existing literature.

The main findings suggest that weekly inflation exhibits asymmetric behavior in which the response to shocks depends upon the location of the price changes in relation to the previous periods.

In general, inflationary shocks above the average have permanent effects on the inflation path. In contrast, deflationary shocks below the average have temporary effects. This conclusion is consistent with the results presented by Maia and Cribari-Neto to the IPCA monthly inflation index. However, we are unable to reject the unit root hypothesis in a broader range of quantiles ($\tau = [0.60; 0.65; 0.70; 0.75; 0.80; 0.85; 0.90; 0.95]$). These results indicates that the asymmetric dynamics of Brazilian inflation is stronger than previously findings would suggest.

The results of the present study contributes to the empirical literature by examining the nature of inflation persistence using higher frequency data and a method which describes the entire conditional distribution of inflation, instead focusing only at its conditional mean. The period under study is concentrated on Inflation Targeting Regime in Brazil, which is different from the previous findings in the literature.

One possible policy implication derived from these findings is that in the Brazilian case the sign and size of a inflationary (or deflationary) shock matter for an optimal response in monetary policy as *postulated* by Fraga et al. (2003). The asymmetric nature of inflation persistence in Brazil suggests that Central Bank must have bigger concern to the inflationary shocks occurring only above the average and not below it. The full inertia hypothesis of the *New Consensus Economics* is supported only at upper tail of the conditional distribution.

When the economy faces a low inflation environment, for instance, the trade liberalization in the 1990's in Brazil, a deflationary shock produced by the productivity growth is very limited in time. This does not mean that productivity growth have no contribution in the long run, but it seems that demand conditions (e.g., fiscal and monetary policy) produce the biggest effect on the inflation path in short and medium run.

In contrast to the low and stable inflation environment, when the current inflation is above the average, like the 2002 currency crisis or a more recent political and fiscal turmoil since 2014, a random shock could produce a permanently higher inflation rate.

We leave to a future research a simulation study to find the effects of inflation volatility on the properties of coefficients obtained not considered in the present context.

References

[1] ARIDA; P. ; RESENDE, A. L. (1984) Inertial Inflation and Monetary Reform in Brazil, *Texto para Discussão n^o 85*, PUC/RIO, pp. 1-30.

[2] ANDREWS; D. W. K. (1993) Exactly median-unbiased estimation of first order autoregressive/unit root models, *Econometrica*, Vol. 61, pp. 139-165.

[3] BACHA, E. (1997) O Plano Real: uma avaliação, In: *O Brasil pós-real: a política econômica em debate*, Campinas, SP: Unicamp/IE, pp. 11-69.

[4] BAUR, D. G.; DIMPFL, T.; JUNG, R. C. (2012) Stock return autocorrelations revisited: A quantile regression approach, *Journal of Empirical Finance*, Vol. 19, pp. 254-265.

[5] BOGDANSKI, J.; TOMBINI, A. A.; WERLANG, S. R. (2000) Implementing Inflation Targeting in Brazil, *Working Paper Series 1*, Brasília: Banco Central do Brasil, pp. 1-29.

[6] BUSATO, M. I.; MOREIRA, R. R.; CAVALCANTI, A. (2009) A Dinâmica Inflacionária no *New Consensus Economics*: uma Análise Crítica, *Análise Econômica*, Porto Alegre, Ano 27, n. 52, pp. 97-117.

[7] CAMPELO, A. K.; CRIBARI-NETO, F. (2003) Inflation Inertia and Inliers: The case of Brazil, *Revista Brasileira de Economia*, Vol. 57(4), pp. 713-739.

[8] CATI, R. C.; GARCIA, M. G. P.; PERRON, P. (1999) Unit Roots in the Presence of Abrupt Governmental Interventions with Application to Brazilian Data, *Journal of Applied Econometrics*, Vol. 14, pp. 27-56.

[9] CORREA, A. S.; PETRASSI, M. B. S.; SANTOS, R. (2016) Price-Setting Behavior in Brazil: survey evidence, *Working Paper Series 422*, Banco Central do Brasil, Brasília, pp. 1-32.

[10] DICKEY, D. A.; FULLER, W. A. (1979) Distribution of the Estimators for Autoregressive Time Series with a Unit Root, *Journal of the American Statistical Association*, vol. 74(366), pp. 427-431.

[11] DORNBUSCH, R.; STURZENEGGER, F; WOLF, H.; FISCHER, S.; BARRO, R. J. (1990) Extreme Inflation: Dynamics and Stabilization, *Brookings Papers on Economic Activity*,Vol. 1990(2), pp. 1-84.

[12] ENGLE, Robert F., MANGANELLI, Simone (2004) CAViaR: Conditional Autoregressive Value at Risk by Regression Quantiles, *Journal of Business & Economic Statistics*, Vol. 22(4), pp. 367-381.

[13] FENG, X.; HE, X.; HU, J. (2011) Wild bootstrap for quantile regression, *Biometrika*, Vol. 98(4), pp. 995-999.

[14] FIGUEIREDO, F. M. R.; FERREIRA, T. P. (2002) Os preços administrados e a inflação no Brasil, *Trabalhos para Discussão*, Banco Central do Brasil, Brasília, nº 59, Dezembro, pp. 1-32.

[15] FIGUEIREDO, E. A.; MARQUES, A. M. (2009) Inflação Inercial como um Processo de Longa Memória: Análise a partir de um Modelo Arfima-Figarch, *Estudos Econômicos*, Vol. 39(2), pp. 437-458.

[16] FIGUEIREDO, E. A.; MARQUES, A. M. (2011) Inflação inercial sob mudanças de regime: análise a partir de um modelo MS-ARFIMA, 1944-2009, *Economia Aplicada*, Vol. 15(3), pp. 443-457.

[17] FRAGA, A., GOLDFAJN, I., MINELLA, A. (2003), Inflation Targeting in Emerging Market Economies, *National Bureau of Economic Research*, NBER Macroeconomics Annual, Volume 18, pp. 365-415.

[18] FRANCO, G. H. B. (1998) A inserção externa e o desenvolvimento, *Revista de Economia Política*, Vol. 18(3), pp. 121-147.

[19] GALVAO, A. F. (2009) Unit root quantile autoregression testing using covariates, *Journal of Econometrics*, vol. 152(2), pp. 165-178.

[20] GRANGER, C. W. J.; HUANG, B.-N.; YANG, C.-W. (2010) A bivariate causality between stock prices and exchange rates: evidence from recent Asian flu, *Quarterly Review of Economics and Finance*, vol. 40, pp. 337-354.

[21] HAYAKAWA, K., MATSUURA, T. (2017) Trade liberalization, market share reallocation, and aggregate productivity: the case of the Indonesian manufacturing industry, *Developing Economies*, vol. 55(3), pp. 230-249.

[22] HOSSEINKOUCHACK; M.; WOLTERS, M. H. (2013) Do large recessions reduce output permanently?, *Economics Letters*,vol. 121, pp. 516-519.

[23] KOENKER; R.; BASSET, G. (1978) Regression Quantiles, *Econometrica*,vol. 46(1), pp. 33-50.

[24] KOENKER; R.; XIAO, Z. (2004) Unit Root Quantile Autoregression Inference, *Journal of the American Statistical Association*,Vol. 99(467), pp. 775-787.

[25] KOENKER; R.; XIAO, Z. (2006) Quantile Autoregression, *Journal of the American Statistical Association*,Vol. 101(475), pp. 980-1006.

[26] KWAITKOWSKI; D.; PHILLIPS, P. C. B.; SCHMIDT, P.; SHIN, Y. (1992) Testing the null hypothesis of stationarity against the alternative of a unit root, *Journal of Econometrics*,Vol. 54, pp. 159-178.

[27] LOPES; F. L. (1985) Inflação inercial, hiperinflação e desinflação: notas e conjecturas, *Revista de Economia Política*,Vol. 5(2), pp. 135-151.

[28] LIMA; L. R., GAGLIANONE, W. P., SAMPAIO, R. M. B. (2008) Debt ceiling and fiscal sustainability in Brazil: A quantile autoregression approach, *Journal of Development Economics*,vol. 86, pp. 313-335.

[29] MAIA; A. L. S., CRIBARI-NETO, F. (2006) Dinâmica inflacionária brasileira: resultados de auto-regressão quantílica, *Revista Brasileira de Economia*,vol. 60(2), pp. 153-165.

[30] MINELLA, A.; FREITAS, P. S.; GOLDFAJN, I.; MUINHOS, M. K. (2002) Inflation Targeting in Brazil: Lessons and Challenges, *Working Paper Series 53*, Brasília, Banco Central do Brasil, pp. 1-47.

[31] NG, S., PERRON, P. (2001) Lag length selection and the construction of unit root tests with good size and power, *Econometrica*, vol. 69, pp. 1519 - 1554.

[32] RESENDE, A. L. (1985a) A moeda indexada: nem panacéia nem mágica, *Revista de Economia Política*, vol. 5(2), pp. 124-129.

[33] RESENDE, A. L. (1985b) A moeda indexada: uma proposta para eliminar a inflação inercial, *Revista de Economia Política*, vol. 5(2), pp. 130-134.

[34] SIMONSEN, M. H. (1985) A inflação brasileira: lições e perspectivas, *Revista de Economia Política*, vol. 5(4), pp. 15-30.

[35] TAYLOR, A. M., TAYLOR, M. P. (2004) The Purchasing Power Parity Debate, *Journal of Economic Perspectives*, vol. 18(4), pp. 135-158.

[36] VIOLA, A. P., KLOTZLE, M. C., PINTO, A. C. F., GAGLIANONE, W. P. (2017) Predicting Exchange Rate Volatility in Brazil: An approach using quantile autoregression, *Working Paper Series 466*, Banco Central do Brasil, Brasília, pp. 1-40.

[37] ZIVOT, E.; ANDREWS, D. W. K. (1992) Further evidence on the great crash, the oil-price shock, and the unit-root hypothesis, *Journal of Business & Economic Statistics*, vol. 10(3), pp. 251-270.