Inflation persistence in BRICS countries: A quantile autoregressive (QAR) model

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INFLATION PERSSITENCE IN BRICS COUNTRIES: A QUANTILE AUTOREGRESSIVE (QAR) APPROACH

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ABSTRACT: Using the recently-introduced quantile autoregression methodology (QAR), this study contributes to the ever-expanding empirical literature by investigating the persistence in inflation for BRICS countries using quarterly time series data collected between 1996 to 2016. Our empirical analysis reveals two crucial findings. Firstly, for all estimated regressions, persistence in moderate to high inflation rates in the QAR regression exhibits unit root tendencies. Secondly, we note that inflation persistence varies across different time horizons corresponding to periods priori and subsequent to the global financial crisis. These findings have important implications for Central Banks in BRICs countries.

Keywords: BRICS; Emerging economies; Inflation persistence; Quantile regression.

JEL Classification Code: C31; E31.

1 INTRODUCTION

Following the turn of the millennium, much emphasis has been placed on the concept of price stability as the core mandate of monetary policy practice by a vast majority of Central banks worldwide. Since then, there has been a multitude of empirical literature which has considered whether monetary policy has been effective at controlling inflation rates or not (Amano (2007), Gaffeo and Canzian (2011), Cioran (2014), Moore (2014), Colucci and Valori (2015) and Cukierman (2017) amongst others). From an academic perspective, the centre of this debate primarily revolves around the issue of whether an observed series of inflation rates behaves as a persistent process over time or exhibits mean-reverting tendencies. At a policy level, a highly persistent inflation process is undesirable since a number of macroeconomic policy models, such as Fisher hypothesis, the expectations-augmented Phillips curve, the traditional capital asset pricing model (CAPM) and the purchasing power parity (PPP) relationship, depend on the assumption of a stationary inflation process. In particular, the forecastability of inflation by monetary authorities and academics alike, is highly distorted if inflation is found to contain unit root characteristics and such persistence in inflation is believed to have been the underlying factor behind the failure of a number of stabilization programmes (Phiri, 2017).

From an econometric perspective, the most straight-forward method of measuring the persistence in an inflation series is to estimate an autoregressive (AR) process of the inflation rate, and determine whether the sum of the AR coefficients (i.e. SARC) of the lag length p, exceeds unity. The rationale underlying this approach is that the SARC of an AR process of an inflation series is equal to or greater than unity, then inflation is deemed to be highly persistence. Conversely, as the SARC approaches zero, then inflation becomes less persistent and increasingly stationary hence rendering the time series more controllable by monetary authorities. Up-to-date, there have been a dearth of empirical studies which have estimated SARC of the inflation process for industrialised countries (Gadzinski and Orlandi (2004), Batini (2006), Cuestas and Harrison (2010), Gerlach and Tillman (2012) and Wolters and Tillman (2015)), developing countries (Khadaroo (2005), Rangasamy (2009), Mourelle et. al.

(2011), Gil-Alana (2011), Phiri (2012, 2016, 2017), Balcilar et. al. (2016), Gil-Alana et. al. (2016) and Gupta et. al. (2017)) and mixed economies (Antonakakis et. al., 2016) with these studies providing a variety of conflicting empirical evidences for the differing economies under investigation.

In this current study, we investigate the inflation persistence for BRICS countries, and to the best of our knowledge, this becomes the first study to do so for this group of emerging economies. Besides the lack of availability of empirical literature surrounding the issue for BRCIS countries, we consider the BRICS countries as an interesting case study since a majority of these emerging economies use inflation targeting policy frameworks as official monetary policy mandates. Hence, the ability of Central Banks in BRICS countries to control the inflation rate can be thought of as a benchmark measure of the success of monetary policy conduct in these countries. Moreover, the BRICS countries are representative of emerging economies which are uniquely characterized by highly developed financial markets and open economies, on one end, and high levels of unemployment and widespread income inequality as well as poverty, one the other end. Consequentially, high levels of inflation persistence in the BRICS countries may prove to be more detrimental to the proper functioning of these economies since BRICS countries rely on stable financial environments in order to implement macroeconomic policies aimed at improving their social statuses.

Of recent, a couple of studies have deviated from the conventional use of the autoregressive (AR) framework in favour of quantile regression framework in capturing the persistence within an inflation process (Tsong and Lee (2011), Manzan and Zerom (2015), Wolters and Tillman (2015) and Gupta et. al. (2017)). As critically discussed in Koenker and Hallock (2001), quantile regressions provide a number of advantages over other conventional estimation techniques. For instance, quantile regressions examine the impact of the dependent variable at many points of the conditional distribution, not only at the centre but also in the tails (Benoit and Van der Poel, 2009). As a consequence, the regression coefficients from quantile regression estimates do not vary by concealing on the target variable for most of the percentiles and hence present a more complete picture of the relationship between the target

variables and the covariates. Moreover, unlike OLS estimates which can be inefficient if the errors are highly non-normal, quantile regression are more robust to non-normal errors and outliers (Koenker and Bassett, 1978). Thus, in light of the aforementioned advantages, we consider the quantile autoregression (QAR) as an excellent choice for modelling the inflation persistence via SARC estimates for the BRICS countries since the QAR model generally allows for certain asymmetric behaviour within a time series, yet retains its computational simplicity.

Having provided this brief background to the study, we structure the rest of the manuscript s follows. The next section of the paper presents the QAR model, the third section of the paper presented the empirical data and empirical QAR regression estimates. The paper is concluded in the fourth section of the paper in the form of policy conclusions.

2 METHODOLOGY

2.1 Baseline AR model of inflation

As previously mentioned, we use the SARC estimates as a means of measuring the persistence in an AR process of an inflation series. This methodology assumes that inflation persistence can be captured as the positive serial correlation in a univariate process of the inflation variable Rangasamy (2009). Denoting π as the inflation process, we specify our AR process of inflation as:

$$\pi_t = \alpha_1 \pi_{t-1} + \alpha_2 \pi_{t-2} + \cdots + \alpha_p \pi_{t-p} \quad (1)$$

From regression (1), inflation persistence (ρ) is measured as the SARC which is computed as:

$$\rho = \alpha_1 + \alpha_2 + \cdots + \alpha_p = \sum_{i=1}^{n} \alpha_p \quad (2)$$

And the decision rule for evaluating the persistence in the inflation process is that inflation is deemed as being persistent if $\rho \geq 1$, thus implying that inflation exhibits unit root tendencies. On the other hand, if $\rho < 1$, then inflation is assumed to be a stationary, mean reverting process.

2.2 Specification of QAR model of inflation

Quantile regression is a method of fitting a regression line through the conditional quantiles of a distribution (Benoit and Van der Poel, 2009). The QAR model by the p-th order AR process with random coefficients used in our study can thus be specified as follows:

$$\pi_t = \alpha_0(\Omega_t) + \alpha_1(\Omega_t)\pi_{t-1} + \cdots \alpha_p(\Omega_t)\pi_{t-p} \quad (3)$$

Where α_i's are unknown functions $[0,1] \rightarrow \Re$ and $\{\Omega_t\}$ is a sequence of iid standard uniform random variables. Under the conditions that $\alpha_0(\Omega_t) + \alpha_1(\Omega_t)\pi_{t-1} + \ldots + \alpha_p(\Omega_t)\pi_{t-p}$ are monotone increasing in Ω_t, then the τth conditional quantile function of π_t can be expressed as:

$$Q_{\pi t}(\tau/F_{t-1}) = \alpha_0(\tau) + \alpha_1(\tau)\pi_{t-1} + \cdots \alpha_p(\tau)\pi_{t-p} \quad (4)$$

Where $Q_{\pi t}(\tau/F_{t-1})$ is the conditional distribution function and equation (4) is now our baseline representative QAR(p) model of inflation. In creating a vector $x_t = (1, \pi_{t-1}, \ldots, \pi_{t-p})'$, the QAR model can be written as :

$$\pi_t = Q_{\pi t}(\tau/F_{t-1}) + e_t = x_t'\beta_\tau + e_t \quad (5)$$

Whereby β_τ , known as the AR quantiles, can be estimated as:

$$\beta_\tau^* = \arg_{\beta \in R^{P+1}} \min_\psi \sum_{t=1}^{T} \rho_\tau(\pi_t - x'_t\beta) \quad (6)$$

Where the function ρ_τ (.) is the quantile loss function defined as $\rho_\tau(u) = u[\tau - I.(u < 0)]$. The minimization problem represented in equation (6) can be easily solved using linear programming methods (Koenker and Bassett, 1978). The conditional density of π_t on x_t can be estimated by the difference quotients:

$$\beta_{\pi t/xt}(\tau) = \frac{\tau_i - \tau_{\tau-1}}{Q_{\pi t/xt}(\tau_i) - Q_{\pi t/xt}(\tau_{i-1})} \quad (7)$$

For some appropriately chosen sequence of τ's i.e. $\tau \in (0, 1)$. In the special case $\tau = 0.5$, the quantile regression delivers the least absolute deviation (LAD) estimation of the OLS model (Koenker and Bassett, 1978).

3 DATA AND EMPIRICAL RESULTS

3.1 Empirical data

All empirical data used in our study consists of annual time series of inflation in consumer prices for Brazil, Russia, India, China and South Africa and all data has been collected for a 20 year period between 1996 and 2016 in quarterly intervals. All time series data has been collected from the International Monetary Fund (IMF) International Financial Statistics database and the summary statistics for the time series are reported in Table 1 below. The reported mean statistics show that inflation averages are highest in Russia and lowest in China. Similarly, the reported standard deviations indicate that inflation is most volatile in Russia and least volatile in South Africa. The skewness, kurtosis and Jarque-Bera (JB) normality test statistics all demonstrate that some of the observed time series are not normally distributed, an observation which strengthens the case for quantile regression over OLS estimates. Above all, the SARC estimates displayed in the last row of Table1 point to inflation rates in all five BRICS countries behaving as stationary process over the full sample

period, with South Africa having the highest rates of persistence and China have least persistent levels.

Table 1: Summary statistics of the time series

	Brazil	Russia	India	China	South Africa
mean	7.00	17.77	7.01	2.23	6.04
s.d.	3.15	18.23	2.99	2.45	2.12
skewness	1.64	2.81	0.59	0.65	0.46
kurtosis	2.32	7.59	-0.89	0.11	1.14
jb (p-value)	0.00***	0.00***	0.38	0.48	0.39
SARC	0.83	0.63	0.91	0.59	0.94

Note: "***", "**","*" represents the 1, 5 and 10 percent significance levels, respectively. The SARC estimates are based on estimates of an AR(p) process of inflation with the optimal lag being selected using the AIC information criterion. The AR estimates are based on heteroscedasticity-robust standard errors.

3.2 QAR regression estimation results

The estimates of the QAR regressions are reported in Tables 2, and has been executed for nine quantiles (i.e. 10^{th} quantile, 20^{th} quantile, 30^{th} quantile, 40^{th} quantile, 50^{th} quantile, 60^{th} quantile, 70^{th} quantile, 80^{th} quantile and 90^{th} quantile). Our empirical results unravel a number of interesting phenomenon. For starters, we observe low levels of inflation persistence, defined as SARC estimates below unity, at observations below the 40^{th} quantile and these gradually begin to increase as one moves up the quantile ranks. We particularly note that the SARC estimates begin to exceed unity after crossing beyond certain quantiles and these limits differ amongst the BRICS countries i.e. 50^{th} quantile for South Africa, 60^{th} quantile for India, 70^{th} quantile for Brazil and 80^{th} quantile for both Russia and China. It is also interesting to note that the range of inflation persistence across the quantiles varies amongst the BRICS ranging from 0.44 to 1.45 for Brazil, 0.24 to 1.87 for Russia, 0.61 to 1.31 for India, -0.11 to 1.23 for China and 0.62 to 1.61 for South Africa. Therefore in contrast to the previously reported SARC estimates of the AR(p) model which indicate stationarity in the

BRICS inflation rates, the SARC estimates based on the QAR estimates point to non-stationarity in the inflation process at moderate to high rates.

Table 2: Full sample SARC estimates

quantile	Brazil	Russia	India	China	South Africa
0.1	0.44	0.24	0.61	-0.11	0.62
0.2	0.46	0.24	0.74	0.34	0.64
0.3	0.81	0.31	0.80	0.34	0.75
0.4	0.87	0.60	0.87	0.49	0.76
0.5	0.96	0.79	0.99	0.72	1.02
0.6	0.97	0.93	1.05	0.73	1.05
0.7	1.04	0.96	0.10	0.73	0.13
0.8	1.32	1.16	1.17	1.00	1.37
0.9	1.45	1.87	1.31	1.23	1.61

Notes: The optimal lag of the QAR regressions are selected using the AIC information criterion.

3.3 Sensitivity analysis

In order to ensure that our preliminary QAR estimates are not biased, we perform sensitivity analysis by incorporating a structural break corresponding to the global financial crisis. We consider the sub-prime crisis as an import structural event since the crisis had a significant effect on inflation rates in most countries worldwide, more prominently so around the 2008 period. Indeed, the previous works of Phiri (2017) demonstrate on how the financial crisis altered the degree of inflation persistence in South Africa. Nevertheless the aforementioned study employs traditional OLS estimates which are founded on the realistic assumption that persistence in the inflation process remains uniform across all levels of inflation. We overcome this shortcoming by re-estimating our QAR regressions of inflation for the BRICS countries which involves splitting our observations into two sub-samples, one corresponding to the pre-crisis period and the other to the post-crisis period. The results of this empirical exercise are recorded in Tables 3 and 4, respectively.

Table 3: Pre-crisis estimates

quantile	Brazil	Russia	India	China	South Africa
0.1	0.44	0.24	0.35	0.34	0.64
0.2	0.45	0.24	0.80	0.34	0.64
0.3	0.46	0.31	0.80	0.34	0.76
0.4	0.61	0.31	0.87	0.47	0.76
0.5	0.86	0.76	0.98	0.47	0.80
0.6	0.86	0.93	0.98	0.73	1.03
0.7	0.97	0.96	1.04	0.73	1.17
0.8	1.24	1.03	1.19	0.73	1.37
0.9	1.52	1.87	1.45	0.73	1.53

Notes: The optimal lag of the QAR regressions are selected using the AIC information criterion.

Table 4: Post-crisis estimates

quantile	Brazil	Russia	India	China	South Africa
0.1	0.81	0.45	0.61	-0.12	0.60
0.2	0.86	0.59	0.74	-0.12	0.62
0.3	0.97	0.59	0.74	0.48	0.62
0.4	0.97	0.60	1.01	0.49	0.76
0.5	1.02	0.83	1.05	0.76	1.02
0.6	0.03	1.16	1.10	1.00	1.05
0.7	1.15	1.23	1.17	1.23	1.13
0.8	1.32	1.33	1.17	1.23	1.38
0.9	1.43	1.60	1.30	1.39	1.63

Notes: The optimal lag of the QAR regressions are selected using the AIC information criterion.

Indeed, our results indicate changing dynamics in the inflation series as moves from the pre-crisis to the post-crisis period. For the case of Brazil, we observe that high persistence in the inflation series begin to emerge at the 80^{th} quantile in the pre-crisis period which reduces to the 50^{th} quantile in the post-crisis period. For high inflation persistence emerges in the 80^{th} quantile and 60^{th} quantile for the pre-crisis and post-crisis periods, respectively. Concerning India, non-stationary trends in the inflation process emerge in the 70^{th} quantile for the pre-crisis periods and 40^{th} quantile for the post-crisis period. For the Chinese data the SARC estimates fall well below unity in all quantiles in the pre-crisis periods whereas inflation turns highly persistence in the 60^{th} quantile during the post-crisis period. Lastly, inflation persistence in South Africa emerges in the 60^{th} quantile in the pre-crisis which is slightly lowered to the 50^{th} quantile in the post-crisis periods. Collectively, our results indicate that inflation has been less controllable by Central Banks in BRICS countries in periods subsequent to the financial crisis, more prominently so for Russia and South Africa.

In summary, the results reported in tables 3 and 4 show that during the pre-crisis period, inflation persistence ranged from 0.44 to 0.52 for Brazil, 0.24 to 1.87 for Russia, 0.35 to 1.45 for India, 0.34 to 0.73 for Chin and 0.64 to 0.53 for South Africa. Conversely, during the post-crisis period, inflation persistence ranged from 0.81 to 1.43 for Brazil, 0.45 to 1.60 for Russia, 0.61 to 1.30 for India, -0.12 to 1.39 for China and 0.60 to 1.63 for South Africa. Overall, these results confirm the importance of accounting for a structural shift attributing to the financial crisis in our empirical analysis.

4 CONCLUSION

Concerned by the lack of empirical evidence documenting levels of inflation persistence amongst BRICS countries, our study sought to fill in this gap by applying quantile regression analysis on a univariate series of the CPI inflation for the BRICS economies using time series collected between 1996 and 2016. In being aware of a possible structural break caused by the sub-prime crisis, we also undertook a sensitivity analysis which involved estimating quantile regression for two-sub sample periods corresponding to

the pre and post financial crisis periods. Our obtained empirical results certainly have important policy implications for Central Banks in BRICS economies as well as for academics worldwide. From a policy point of view, monetary authorities on BRICS countries should aim at keeping inflation as low as possible. As our results show that even moderate levels of inflation in these countries are highly persistent. This holds more prominently so for Brazil, India and South Africa in post-crisis periods. From an academic perspective, we encourage future researchers to investigate inflation dynamics across different quantiles for various economies, and in particular, inflation targeting countries. Such an empirical exercise can be undertaken via other univariate quantile regressions like the quantile regression unit root tests or the quantile regression GARCH (QR-GARCH) models.

REFERENCES

Amano R. (2007), "Inflation persistence and monetary policy: A simple result", *Economic Letters*, 94(1), 26-31.

Antonakakis N., Cunado J., Gil-Alana L. and Gupta R. (2016), "Is inflation persistence different in reality?", *Economic Letters*, 148, 55-58.

Balcilar M., Gupta R. and Jooste C. (2016), "Analysing South Africa's inflation persistence using an ARFIMA model with Markov-switching fractional differencing parameter", *The Journal of Developing Areas*, 50(1), 47-57.

Batini N. (2006), "Euro area inflation persistence", *Empirical Economics*, 31(4), 977-1002.

Benoit D. and Van der Poel D. (2009), "Benefits of quantile regression for the analysis of customer lifetime in a contractual setting: An application in financial services", *Exert Systems with Applications*, 36, 10475-01484.

Canarella G. and Miller S. (2015), "Inflation persistence and structural breaks: The experience of inflation targeting countries and the USA", *Journal of Economics Studies*, 43(6), 980-1005.

Cioran Z. (2014), "Monetary policy, inflation and the causal relation between the inflation rate and some of the macroeconomic variables", *Procedia Economics and Finance*, 16, 391-401.

Colucci D. and Valori V. (2015), "Stabilizing inflation in a simple monetary policy model with heterogeneous agents", *Mathematics and Computers in Simulation*, 108, 233-244.

Cuestas J. and Harrison B. (2010), "Inflation persistence and nonlinearities in Central and Eastern European countries", *Economic Letters*, 106, 81-83.

Cukierman A. (2017), "Money growth and inflation: Policy lessons from a comparison of the UK since 2008 with hyperinflation Germany in the 1920s", *Economic Letters*, 154, 109-112.

Gadzinski G. and Orlandi F. (2004), "Inflation persistence in the European Union, the Euro area and the United States", ECB Working Paper Series No. 414, November.

Gaffeo E. and Canzian G. (2011), "The psychology of inflation, monetary policy and macroeconomic instability", *The Journal of Socio-Economics*, 40(5), 660-670.

Gerlach S. and Tillman P. (2012), "Inflation targeting and inflation persistence in Asia-Pacific", *Journal of Asian Economies*, 23(4), 360-373.

Gil-Alana L. (2011), "Inflation in South Africa: A long memory approach", *Economics Letters*, 111(3), 207-209.

Gil-Alana L., Mervar A. and Payne J. (2016), "The stationarity of inflation in Croatia: Anti-inflation stabilization program and the change in persistence", *Economic Change and Restructuring*, 50(1), 45-58

Gupta R., Jooste C. and Ranjbar O. (2017), "South Africa's inflation persistence: A quantile regression framework", *Economic Change and Restructuring*, (forthcoming).

Khadaroo A. (2005), "A threshold in inflation dynamics: Evidence from emerging countries", *Applied Economics*, 37(6), 719-723.

Koenker R. and Bassett G. (1978), "Regression Quantiles", *Econometrica*, 46(1), 33-50.

Koenker R. and Hallock K. (2001), "Quantile regression", *Journal of Economic Perspectives*, 15(4), 143-156.

Koenker R. and Xiao Z. (2006), "Quantile autoregression", *Journal of American Statistical Association*, 101(475), 980-1006.

Manzan S. and Zerom D. (2015), "Asymmetric quantile persistence and predictability: The case of the US inflation", *Oxford Bulletin of Economics and Statistics*, 77(2), 297-318.

Moore B. (2014), "Monetary policy regimes and inflation in the new-Keynesian model", *Journal of Macroeconomics*, 40, 323-337.

Mourelle E., Cuestas J. and Gil-Alana L. (2011), "Is there an asymmetric behaviour in African inflation? A nonlinear approach", *South African Journal of Economics*, 79(1), 68-90.

Phiri A. (2012), "Threshold effects and inflation persistence in South Africa", *Journal of Financial Economic Policy*, 4(3), 247-269.

Phiri A. (2016), “Inflation persistence in African countries: Does inflation targeting matter”, *Economics and Business Letters*, 5(3), 65-71.

Phiri A. (2017), “Changes in inflation persistence prior and subsequent to the subprime crisis: What are the implications for South Africa?”, *Journal of Reviews in Global Economics*, 6, 198-207.

Rangasamy L. (2009), “Inflation persistence and core inflation: The case of South Africa”, *South African Journal of Economics*, 77(3), 430-444.

Tsong C. and Lee C. (2011), “Asymmetric inflation dynamics: Evidence from quantile regression analysis”, *Journal of Macroeconomics*, 33(4), 668-680.

Wolters M. and Tillman P. (2015), “The changing dynamics of US inflation persistence: A quantile regression approach”, *Studies in Nonlinear Dynamics and Econometrics*, 19(2), 161-182.