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BRICS countries: real interest rates and long memory

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Abstract

This paper analyzes the degree of persistence of the ex-post real interest rates of the BRICS (Brazil, Russia, India, China, and South Africa) using long-memory ARFIMA models, as well as unit root tests with structural breaks. For the period ranging from July 2000 to December 2012, the results show very high persistence, and non-stationarity but mean reversion for all countries, except for Russia, which showed signs of non-stationarity and no mean reversion. However, when structural breaks were accounted for, the results indicate that part of the persistence found previously in the real interest rates of China, South Africa and India was due to those breaks. Brazil was not influenced by the breaks but was able to keep its pattern of high persistence, but with mean reversion. Russia, on the other hand, kept its pattern of non-stationarity and no influence of breaks.

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1. Introduction

The understanding of the properties of interest rate dynamics has been examined at length, both theoretically and empirically. For instance, according to the Fisher effect, expected inflation and nominal interest rates move together in the long run and, as a consequence, ex-ante real interest rates must be stable in the long term, with mean reversion and no unit root. However, they can have a high degree of persistence and exhibit long memory.

In other words, the analysis of the statistical properties of real interest rates can be closely related to examining the stationarity of a series. But studying whether interest rates are either I(0) or I(1) can lead to spurious results, once such type of test does not allow for the presence of fractional numbers. The Autoregressive Fractionally Integrated (ARFIMA) models are able to provide much more flexibility when contrasted to the usual unit root dichotomy, once there is the possibility of including intermediate degrees of integration (between 0 and 1).[1] As a result, there is the possibility of finding a series that, in spite of exhibiting mean reversion, shows signs of high persistence and, therefore, a long memory process. Nevertheless, such persistence can also be a result of structural breaks in the series. In fact, Diebold and Inoue (2001) and Granger and Hyung (2004) have shown that fractional integration and structural breaks are closely related issues and should be considered as part of an empirical investigation to address time series persistence.

The aim of this paper is to overcome the use of the classical unit root tests, which work with only the possibility of having a unit root or not, and analyze the process of long memory in real interest rates for the BRICS (Brazil, Russia, India, China, and South Africa) based on ARFIMA univariate models, as well as unit root tests with structural breaks. For the period ranging from July 2000 to December 2012, the initial results show very high persistence, and non-stationarity, for all of the interest rates examined, except for Russia. However, when the long memory models take into account the possibility of endogenous structural breaks, the second round of tests show that a considerable part of the persistence found previously is due to those breaks, meaning that real interest rates are predominantly stationary with mean reversion. The exception is South Africa, which shows a real interest rate with signs of a unit root process.

The article is structured as follows. Section 2 brings the literature review related to the topic. Section 3 deals with the econometric methodology and the data. Section 4 discusses the results, and the last section summarizes the article.

2. Literature Review

The literature relating interest rates and fractional integration is interesting and has been growing recently. Shea (1991) bootstraps fractionally integrated models for tests of the expectations hypothesis of the term structure of interest rates and finds that, when the possibility of long memory is accounted for, there is an enhancement of the model. Phillips (2005) estimates modified log periodogram regression models for the American real interest rates, finding that they are (fractionally) nonstationary during the period 1934–1997, as well as for more recent sub periods 1961–1985 and 1961–1997. The estimations also reject nonstationarity and short memory stationarity for the periods analyzed.

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[1] Diebold and Rudebusch (1991), Hassler and Wolters (1994) and Lee and Schmidt (1996) address the importance of using fractional integration in the context of unit roots, especially when considering the lack of power of traditional unit root tests (ADF and KPSS) against this type (fractionally-integrated) of alternatives.

Specifically regarding ARFIMA models, Gil-Alana (2003) estimates the behavior of short run interest rates in some Asian emerging economies (Singapore, Thailand, Malaysia, South Korea, and Philippines) and find mean reversion for the Thai and Singaporean interest rates, and less conclusive results for the other countries.

Iglesias and Phillips (2005) use ARFIMA models to study the behavior of short-term interest rates of six European countries (Denmark, Portugal, Spain, Germany, Netherlands and Switzerland) based on daily data in the 1990s. They find that that Swiss rate seems to be the only one time series that follows clearly an I(1) process.

Couchman, Gounder and Su (2006) examine the long memory properties of three real interest rates, the realized (ex-post) rate and two ex-ante rates, for 16 countries. The majority of the series have long-memory parameters between zero and one, and they tend to be considerably smaller for the ex-post real rates compared with both of the two ex-ante rates.

Candelon and Gil-Alana (2006) analyze the short-run interest rates in several emerging economies (Singapore, Thailand, Mexico, Malaysia, Philippines and South Korea) by means of fractional integration. The authors find that only for Singapore and Thailand the nominal interest rates are mean-reverting.

Lai (1997) analyzes the U.S. real interest rates, from 1973 through 1994, and reports evidence that both ex-ante and ex-post rates are fractionally integrated and also exhibit mean reversion. A similar result is found by Tsay (2000). Karanasos, Sekioua and Zeng (2006) model the dynamics of U.S. ex-post and ex-ante real interest rates, searching for new evidence from over a century of data. Their results suggest that a lot of attention should be paid to the degree of persistence of the series.

Gil-Alana (2002) also models the U.S. interest rate using ARFIMA models and shows that there is a reduction in the order of integration of the series, from I(0,79) to I(0,61), when a mean shift is included to take into consideration the turbulence period at the beginning of the 1980s. Gil-Alana (2004) makes use of the fractionally integrated methodology to estimate the order of integration of the U.S. long-term interest rate. For the period ranging from 1940 to 2000 the author cannot reject the hypothesis of a unit root, but he finds some fractional integration for the period 1978–2000.

Caporale and Gil-Alana (2009) model the degree of persistence of the U.S. Federal Funds effective rate using fractional integration, from July 1954 through March 2008. According to the authors, the fractional estimations seem to be very sensitive to the choice of the I(0) error term. For uncorrelated disturbances, the order of integration is strictly above 1, whilst autocorrelated errors generate order of integration strictly below 1.

In relation to the BRICS countries, Gomes da Silva and Leme (2011) make use of ARFIMA models to analyze the Brazilian interest rate persistence, without accounting for structural breaks. For the period ranging from August 1995 to May 2008, the authors find that the *Selic* Rate is persistent, non-stationary, but shows mean reversion in the long run.

Other articles are worth mentioning. For instance, Aye et al (2013) examine the time series behavior of South Africa's house prices within a fractional integration modelling framework, while identifying potential breaks and outliers. The results indicate that, once structural breaks are identified, there is persistence in the series. Fadiran and Ezeoha (2012) investigate the short and long run interest rate transmission mechanism (money market rate to retail interest rate) for South Africa, using error correction (ECM) and ECM-EGARCH models in order to address the impact of interest rate volatility and the leverage effect. The results suggest that the pass through is incomplete in the long run and largely incomplete in the short run, with the presence of asymmetry in the lending rate rigidity adjustment downward and a symmetric upward rigidity adjustment in the deposit rate. The authors also show evidence supporting the presence of collusive price arrangements in the retail rates indicating the existence of bank concentration and high net interest margin.

3. Econometric Methodology and Data

3.1 ARFIMA Models and Structural Breaks

The persistence analysis can be performed by the use of several unit root tests found in the literature. Given that the series' order of integration 'd' assumes only integer values, i.e. I(0) if stationary and I(1) if not. The ARFIMA (Autoregressive Fractionally Integrated Moving Average) methodology[2], as defined by Granger and Joyeux (1980) and Hosking (1981), generalizes ARIMA models (p, d, q) and allows for fractional values of the order of integration 'd' between 0 and 1. In other words, the flexibility of the ARFIMA models increases the acuity of the analysis by better defining each series' degree of persistence – a step forward in relation to the rigid unit root tests. Moreover, ARFIMA models improve the low power of the unit root test and are also capable of modeling the dynamics of short and long run processes through the estimation of impulse response functions.

In fact, low levels of 'd' characterize weak persistence in the ARFIMA models, while in the traditional unit root models this means no persistence, in the majority of cases[3]**.** On the other hand, high levels of 'd' are considered persistent with reversion to the mean, whereas in the traditional unit root tests such persistence exists, but with no reversion to the mean. In sum, ARFIMA models have the following rules: 1) if $0 < d < 0.5$, the series is stationary with reversion to the mean; 2) if $0.5 \leq d < 1$, the series is non-stationary but still mean reverting; 3) if $d \geq 1$, the series is non-stationary and does not have mean reversion (Gil-Alana, 2001). Finally, if $d < 0$ the process is said to be "anti-persistent".

Three estimation methods of the ARFIMA models are commonly used: Exact Maximum Likelihood (EML), Modified Profile Likelihood (MPL), and Nonlinear Least Squares (NLS). By definition, both EML and MPL impose $-1 < d < 0.5$. If the model includes regressor variables and the sample is small, the MPL is preferred over the EML. The NLS methodology allows for $d > -0.5$ and can be used in the estimation of nonstationary series (Baillie, Chung and Tieslau, 1996). Given that the series analyzed seem to be nonstationary, the EML methodology does not apply because it is seriously biased downwards for 'd' values close to 0.5 and greater than 0.5. Therefore, we make use of the NLS methodology, which does not present these usual biases.

Besides examining the long memory properties of the series, it is important to check whether they have structural breaks. This is essential once, as mentioned, one may conclude that a series has a long memory process when it has actually been influenced by structural breaks.

In order to examine the order of integration of the series we first apply unit root tests, such as ADF and KPSS. However, since Perron (1989), it is well known that ADF tests can fail to reject a false unit root due to misspecification of the deterministic trend. In fact, Perron (1989, 1997) and Zivot and Andrews (1992) extend the ADF test considering an exogenous and an endogenous break to avoid this problem.

Clemente, Montañés and Reyes (1998), as argued in Baum (2005), propose a unit root test which extends Perron and Vogelsang's (1992) statistics and account for the possibility of two structural breaks within two types of events: either additive (AO) or innovational (IO) outliers. The first one deals with a sudden change in the series, whereas the second one deals with a gradual shift in the mean of the series.[4]

[2] See Hamilton (1994) for more details.

[3] Even in the case of stationarity detected by a traditional unit root, there is still the possibility of persistence if the process is, for instance, autocorrelated. For example, an ARMA model is I(0) but can be persistent as long as the AR component is large.

[4] See Perron (1989), Banerjee et al. (1992); Christiano (1992); Zivot and Andrews (1992); Perron (1997) or Vogelsang and Perron (1998) as part of the literature on structural break tests for breaking trend variables and

3.2 Data

The database refers to the ex-post real interest rates for the following BRICS countries: Brazil, Russia, India, China and South Africa. The period under analysis ranges from July 2000 up to December 2012. Table 1 reports the descriptive statistics of the data. For the period analyzed, Brazil has the highest average real interest rate (7.59%), followed by China (3.43%). The highest real interest rate also belongs to Brazil (12.95%), whilst the lowest value is found in India (-11.16%). Brazil is also the only one with no negative real interest rate (1.37%).[5]

Table 1
Descriptive Statistics: Real Interest Rates (% p.a.)

COUNTRY	Mean	Median	Maximum	Minimum	Std. Dev.
Brazil	7.59	8.05	12.95	1.37	2.81
Russia	1.65	1.60	8.02	-4.00	2.55
India	-0.92	-0.06	9.73	-11.16	3.44
China	3.43	3.73	7.24	-1.13	2.04
South Africa	2.71	2.65	8.07	-1.50	2.28

Number of Observations = 150
Source: Bloomberg

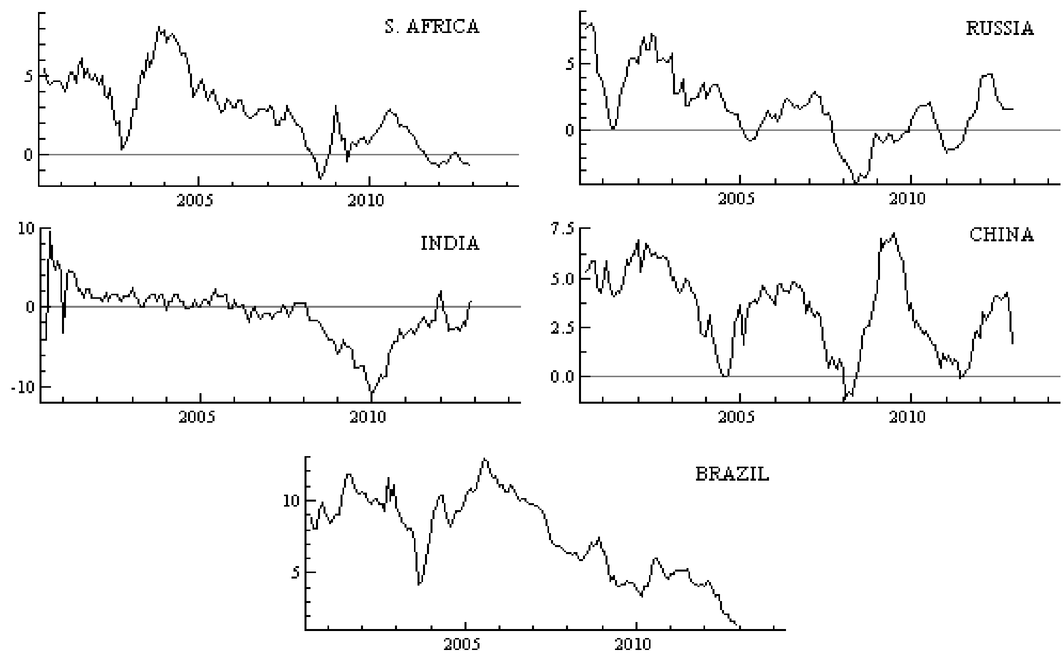
Figure 1 describes the time pattern for the real interest rates for each of the BRICS, from July 2000 to December 2012. In general, one can notice a significant decrease in the Brazilian and South African real interest rates, with the latter even showing negative figures in the recent period. Russia also showed a decrease in its real interest rates. However, after the 2008-2009 crisis, there was an upward trend in the series. India faced negative real interest rates from 2007 up to October 2012, with its lowest value found in the beginning of 2010. Real interest rates in China have exhibited a series of ‘V’ shaped pattern since 2005.

In fact, there has been a clear downward trend in real interest rates for this set of emerging countries. Such behavior is due to less expansionary monetary policies and nominal interest rates cuts, as well as relatively low and stable inflation rates. Among the BRICS countries, Brazil used to have a long history of high interest rates, but there has been a significant decrease in the rates lately, with well-known beneficial effects in the economy through different channels. As for other experiences among the BRICS countries, Russia achieved lower levels of real interest rates, especially after 2005, with an average of 0.43% until December 2012. However, especially after 2010, the country went through a series of real interest rate increases, with an average rate of 1.21% for the period of 2010-2012. Specifically in 2012, the Russian real interest rate averaged 2.89%, and this was due to relatively stable nominal interest rates but higher inflation rates in the second half of 2012.

Perron (1990) and Perron and Vogelsang (1992) when only a shift in the mean is present. See also Lee and Strazicich (2003) for an endogenous two-break LM unit root test.

[5] Data source: Bloomberg.

Figure 1
Real Interest Rates: BRICS



Source: Bloomberg

4. Results

4. 1 Conventional Unit Root Tests

As a benchmark, we start by estimating conventional ADF, PP and KPSS[6] unit root tests for all series (Table 2). Using a 5% level of significance, the ADF and PP estimations reject the unit root hypothesis for Russia and India, but not for the remaining countries. As for the KPSS test, it rejects the null (stationarity) for all countries (China at only 10%).

Table 2
Conventional Unit Root Tests – BRICS Real Interest Rates (%)

COUNTRY	ADF				PP				KPSS			
	Test Stats	Lag	Critical Values		Test Stats	*Band Width*	Critical Values		Test Stats	*Band Width*	Critical Values	
			5%	10%			5%	10%			5%	10%
Brazil	-0.74	3	-2.88	-2.57	-0.72	2	-2.88	-2.57	1.04*	10	0.46	0.34
Russia	-3.09*	4	-2.88	-2.57	-2.93*	7	-2.88	-2.57	0.75*	9	0.46	0.34
India	-3.17*	0	-2.88	-2.57	-3.00*	4	-2.88	-2.57	0.90*	10	0.46	0.34
China	-2.26	12	-2.88	-2.57	-2.47	6	-2.88	-2.57	0.40**	9	0.46	0.34
South Africa	-1.51	9	-2.88	-2.57	-1.65	3	-2.88	-2.57	1.02*	10	0.46	0.34

Note: Estimations with constant only. *, ** mean rejection of the null at 5% and 10%

However, Baillie et al. (1996) argued that when the KPSS rejects the null hypothesis and the reason is fractional integration, the PP test should reject the unit root null hypothesis, which is the case only for India and Russia. Thus, following the authors' procedure, one

[6] See Dickey and Fuller (1979), Phillips and Perron (1988) and Kwiatkowski, Phillips, Schmidt and Shin (1992).

would come to the conclusion that the majority of the series tested have a unit root, as there is rejection of the null in all KPSS tests and only two rejections in the PP (and ADF) estimations. But, as mentioned before, ADF and PP-type tests have lower power to make a distinction between unit root and near unit root processes. There is still a chance of confusion between a long memory process and a structural break, which will be checked further on.

4.2 Unit Root Tests with Structural Breaks

In order to examine the order of integration of the series, taking into consideration the possibility of occurrence of breaks, we make use of a two-break unit root test proposed by Clemente, Montañés and Reyes (1998).

Table 3
Two Break Unit Root Test - Monthly Data (July 2000 to December 2012)

COUNTRY	AR(k)	Test Statistic	Break Dates		1st Break	2nd Break
			1st Break	2nd Break	D_{1t} (t-stat)	D_{2t} (t-stat)
Brazil	9	-1,82	Jul 2003	Sept 2007	-0,07 (-0.22)	-4.72 ** (-16.12)
Russia	8	-3,01	Mar 2003	Nov 2007	-3.10** (-7.17)	-1.56** (-4.55)
India	5	-3,25	Oct 2008	Aug 2010	-7.88** (-16.55)	5.10** (8.85)
China	12	-2,08	Mar 2009	Jan 2010	2.18** (3.61)	-3.799 ** (-5.792)
South Africa	0	-3,22	Jun 2003	Dec 2004	2.45** (5.77)	-4.95** (-13.08)

Note: ** means rejection of H_0 at 1% .
Two Break Unit Root tests using the clemao2 command – Two Break, Addictive Outlier using Stata 11

Table 3 summarizes the results and shows that there is no rejection of the null, indicating that the real interest rates analyzed are nonstationary. The estimated coefficients for the two break dummies (D_{1t} and D_{2t}) are all significant at the 1% level, except for the first break in Brazil (July 2003). Therefore, the results related to the two-break unit root tests are in line with those found in the conventional unit root tests (Table 2), since the majority of the series tested have a unit root and all the series are nonstationary when using the two-break unit root test. The next step is to incorporate these breaks and investigate the long memory process for each country.

4.3 ARFIMA Results

For the ARFIMA (p, d, q) estimations we follow the standard procedure of using Autoregressive (AR) and Moving Average (MA) representations up to the third lag, generating 16 different estimations for each model. After that, we make use of the Schwarz Information Criterion (SIC) to select the best model for each of the series.[7]

Before choosing the best model, we can look at the ARFIMA (0, d, 0) estimations, without any AR or MA component, to see whether they generate 'd' parameters close to a unit root or not. Table 4 reports that only India (d = 0.746) has a 'd' value which is not close

[7] Although the Schwarz Information Criteria is a correct way of selecting a model, we are fully aware that it is not necessarily the best one in applications involving fractional integration. As mentioned by Hosking (1981) (1984), the Schwarz Criteria (SIC), as well as the Akaike Information Criteria (AIC), focuses on the short-term forecasting ability of the fitted model and may not give sufficient emphasis to the long-run properties of the ARFIMA models. Beran et al (1998) propose different versions of the AIC, the Bayesian Information Criteria (BIC) and the Hannan and Quinn Criteria (HQ) to be used in fractional autoregressions, but these criteria do not take into account the moving average components.

to or larger than 1. The other remaining countries seem to have non-stationary real interest rates with no mean reversion.

At 5% level, the null hypothesis 'd' = 0 is rejected for all series, meaning that the pure stationarity found for Russia and India in the conventional unit root tests might not really be the case. As for the null hypothesis 'd' = 1, there are some mixed results. The null is not rejected for Brazil, China and South Africa, i.e., for these nations, there is evidence in favor of persistence caused by long memory or a perfect unit root. On the other hand, the null is rejected for Russia and India.

Table 4
ARFIMA Estimations

COUNTRY	ARFIMA (0, d, 0)			ARFIMA (p, d, q)	
	ARFIMA (0, d, 0)	H_0: d=0	H_0: d=1	ARMA (p, q)	'd' [p value]
	'd'	t test [p value]	t test [p value]		
Brazil	1.149	t = 13.04 [0.000]	t = 1.70 [0.091]	(0, 2)	0.829 [0.000]
Russia	1.206	t = 15,35 [0.000]	t = 2,63 [0.009]	(0, 0)	1.206 [0.000]
India	0.746	t = 11.3 [0.000]	t = -3,84 [0.0002]	(2, 1)	0.897 [0.000]
China	1.056	t = 14.6 [0.000]	t = 0.78 [0.4338]	(0, 0)	1.056 [0.000]
South Africa	0.999	t = 92591.9 [0.000]	t = -0.648 [0.5179]	(0, 1)	0.993 [0.000]

As for the best models selected, Table 4 shows that the real interest rates for Brazil (d = 0.829) and India (d = 0.897) can, so far, be characterized as non-stationary but with mean reversion. South Africa has also a similar behavior, but its parameter (d = 0.993) is much closer to 1. On the other hand, China (d = 1.056) and Russia (d = 1.206) can both be taken as having real interest rates which are non-stationary and without mean reversion.

However, we need to ask whether breaks are interfering in the results described earlier. A further deeper analysis must be carried out, and this will be done in the next section.

4.4 Fractional Integration and Structural Breaks

Going one step ahead, there is still the possibility of misinterpretation between long memory and structural breaks. Therefore, we have to ask whether the ARFIMA usual procedure is overestimating the parameter 'd' due to the omission of occasional structural breaks.

By making use of the break dates selected by Clemente, Montañés and Reyes' (1998) unit root tests (Table 3), we employ Granger and Hyung´s (2004) procedure, which is based on the residuals of the following regression: $y_t = \beta' Z_t + \xi_t$, where 'y' represents one of the series to be analyzed and 'Z_t' contains the corresponding deterministic terms of unit root tests with breaks. After that, we estimate other ARFIMA models. If this procedure is able to generate lower 'd' values, then the long memory process might well be due to the breaks.

Table 5 reports these results. First of all, the ARFIMA (0, d, 0) estimations, without any AR or MA component, indicate that the point estimation of 'd' shows no improvement for Brazil (from d = 0.829 to d = 1.073) and Russia (from d = 1.206 to d = 1.098). As for China (from d = 1.056 to d = 0.849), South Africa (from d = 0.993 to d = 0.877), and mainly for India (from d = 0.897 to d = 0.173), the 'd' parameter estimations decreases. Thus, it seems that the omission of occasional breaks in the previous investigation leads to overestimated coefficients for these three remaining countries. When we test whether 'd' = 0, at 5% level, the null hypothesis is rejected for all the series analyzed. On the other hand, when we test whether 'd' = 1, the null is rejected only for the case of India.

It means, therefore, that when breaks are taken into consideration, the Russian real interest rate seems to be non-stationary with no mean reversion, as detected by the previous unit root tests. As for Brazil, its real interest rate has got some degree of persistence, with signs of non-stationarity but with mean reversion. The same applies for China, South Africa and India, but these countries' results are influenced by structural breaks.

Table 5
ARFIMA (0, d, 0) for Residuals - Granger & Hyung's Procedure

COUNTRY	ARFIMA (0, d, 0)	H_0: d=0 t test [p value]	H_0: d=1 t test [p value]
Brazil	1.073	t = 12.7 [0.000]	t = 0,87 [0.38]
Russia	1.098	t = 14.3 [0.000]	t = 1.28 [0.20]
India	0.173	t = 0.080 [0.033]	t = -10.26 [0.0001]
China	0.849	t = 11.0 [0.000]	t = -1.95 [0.0531]
South Africa	0.877	t = 9.91 [0.000]	t = -1.39 [0.166]

Final Remarks

This article aimed at analyzing the degree of persistence of the ex-post real interest rates for the following BRICS countries (Brazil, Russia, India, China, and South Africa), for the period ranging from July 2000 up to December 2012.The purpose was to examine whether the real interest rates followed a perfect unit root or a long memory process.

Examining the behavior of real interest rates among the BRICS since mid 2000, it is easy to notice that there is a clear downward trend in real interest rates with potential benefits for the economy. One can say that this trend is important for this set of emerging economies so that they can be in the same path compared to advanced economies, regardless of difference in magnitudes, where the adoption of widespread expansionary monetary policies has been the rule, facing close to zero nominal interest rates and low or even negative real interest rates.

The initial results showed very high persistence, and non-stationarity, for all of the interest rates examined. However, when the long memory models took into account endogenous structural breaks, the second round of tests showed that part of the persistence found previously in the real interest rates of China, South Africa and India was due to those breaks. Brazil was not influenced by breaks, despite being able to keep its pattern of high persistence, but with mean reversion. Russia, on the other hand, kept its pattern of non-stationarity and no influence of breaks.

As for future research, two alternative approaches might be taken. The first one is to model jointly long memory, structural breaks and GARCH type models (Karanasos and Kartsaklas, 2009). A second one is to use methods that deal simultaneously with fractional integration and breaks at unknown periods of time (Gil-Alana, 2008).

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