

# Long-range dependence in interest rates and monetary policy <sup>☆</sup>

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## Abstract

This Letter studies the dynamics of Brazilian interest rates for short-term maturities. The Letter employs developed techniques in the econophysics literature and tests for long-range dependence in the term structure of these interest rates for the last decade. Empirical results suggest that the degree of long-range dependence has changed over time due to changes in monetary policy, specially in the short-end of the term structure of interest rates. Therefore, we show that it is possible to identify monetary arrangements using these techniques from econophysics.

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## 1. Introduction

The analysis of persistence in interest rates is a fundamental question in macroeconomics and finance. In macroeconomics, since monetary policy is implemented through the setting of short-term interest, the term structure of interest rates carries information regarding expectations of future movements in short-term interest rates. However, very little research has been conducted to study changes in the dynamics of persistence in interest rates.

This Letter presents a contribution to the literature by studying whether changes in monetary policy stance, namely the implementation of an inflation targeting regime and adoption of a floating exchange rate regime, produce a change in the persistence of interest rates. We measure persistence in this Letter employing two developed techniques in econophysics, which are the detrended fluctuation analysis (DFA) [1,2] and Generalized Hurst exponents (GHE) [3]. We show that changes in

monetary policy produce a substantial change in persistence of interest rates, specially for short-term interest rates.

This Letter proceed as follows. In Section 2 a brief review of literature is presented. In Section 3 the approaches used to evaluate the Hurst's exponent are presented. In Section 4, the data used in this work is described. In Section 5, empirical results are presented. Finally, Section 6 concludes the Letter.

## 2. Brief literature review

Recent research has studied whether long-range dependence in asset returns and volatility changes over time, and has provided evidence of time-varying long-range dependence [4,5]. Nonetheless, while the presence of long-range dependence in asset returns and returns volatility seems to be an stylized fact,<sup>1</sup> only few papers have provided empirical evidence of long-range dependence in interest rates [8–16].

This Letter contributes to the literature by studying changes in long-range dependence parameters in interest rates time series. We focus on the Brazilian economy due to recent changes that occurred in monetary policy, with the adoption of an inflation targeting regime and a floating exchange rate regime.

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<sup>1</sup> For details, see Mandelbrot [6] and Willinger et al. [7].

### 3. Measures of long-range dependence

There are several methods that may be used to take into account the long-range dependence phenomena.<sup>2</sup> However, in spite of the existence of several methods, the task of calculation the Hurst exponent is not straightforward and the methods sometimes present incompatible estimations of the long-range dependence parameter.

In this Letter we follow two different approaches. The method introduced by Barabási and Vicsek [3] and used recently by Di Matteo et al. [21] to measure the degree of market development of several financial markets. According to Di Matteo et al. [21], it combines sensitivity to any type of dependence in the data and simplicity. Moreover, since it does not deal with max and min functions, it is less sensitive to outliers than the popular R/S statistics. And, also, the detrended fluctuation analysis (DFA) which was developed independently in [1] and [2] and provides an alternative for the determination of the Hurst exponent.

#### 3.1. Generalized Hurst exponent

Let  $Y(t)$  be the integrated time series of logarithm returns, i.e.,  $Y(t) = \log(X(t))$ . The generalized Hurst exponent is a generalization of the approach proposed by Hurst. Barabási and Vicsek [3] suggest analyzing the  $q$ -order moments of the distribution of increments, which seems to be a good characterization of the statistical evolution of a stochastic variable  $Y(t)$ ,

$$K_q(\tau) = \frac{\langle |Y(t+\tau) - Y(t)|^q \rangle}{\langle |Y(t)|^q \rangle}, \quad (1)$$

where the time-interval  $\tau$  can vary.<sup>3</sup> The generalized Hurst exponent can be defined from the scaling behavior of  $K_q(\tau)$ , which can be assumed to follow the relation

$$K_q(\tau) \sim \left(\frac{\tau}{\nu}\right)^{qH(q)}. \quad (2)$$

#### 3.2. Detrended fluctuation analysis

Let  $Y(t)$  be the integrated time series of logarithm returns, i.e.,  $Y(t) = \log(X(t))$ . So, one considers the  $\tau$ -neighborhood around each point  $Y(t)$  of the time series. The local trend in each  $\tau$ -size box is approximated by a polynomial<sup>4</sup> of order  $m$ , namely  $Z(t)$ .

Then, one evaluates the local roughness, namely

$$w^2(Y, \tau) = \frac{1}{\tau} \sum_{t \in \tau} (Y(t) - Z(t))^2. \quad (3)$$

<sup>2</sup> A survey of these methods may be found in Taqqu et al. [17] and Montanary et al. [18]. See also Hurst [19], Lo [20] and Willinger et al. [7].

<sup>3</sup> For  $q = 2$ , the  $K_q(\tau)$  is proportional to the autocorrelation function  $\rho(\tau) = \langle Y(t+\tau)Y(t) \rangle$ .

<sup>4</sup> This polynomial of order  $m$  is usually a first order polynomial, i.e., a straight line where the parameters are determined by a least square fitting.

Moreira et al. [1] showed that

$$\langle w^2(\tau) \rangle \sim \tau^{2H}. \quad (4)$$

### 4. Data

The data considered here are interest rate swaps maturing on 1, 3, 6 and 12 months' time, which are the maturities available for a "long time" span (more than 10 years of data). In these contracts, a party pays a fixed rate over an agreed principal and receives a floating rate over the same principal, the reverse occurring with his or her counterpart. There are no intermediate cash-flows, with the contracts being settled on maturity. The floating rate is the overnight CDI rate (interbank deposits), which tracks very closely the average rate in the market for overnight reserves at the central bank. The fixed rate, negotiated by the parties, is the one used on this Letter.

These contracts have been traded over-the-counter in Brazil since the early 90s, and have to be registered either on Bolsa de Mercadorias e de Futuros – BMF (a futures exchange) or on Central de Títulos Privados – CETIP (a custodian).

We use data on interest rates swaps due to the lack of good quality data on government bond indices for different maturities. Nonetheless, these interest rates are used as benchmarks in the Brazilian financial market. The data is sampled daily, beginning on January 2, 1995 and ending on May 30, 2006. The full sample has 2828 observations, collected from the Bloomberg system.

It is worth mentioning that in the past decade the Brazilian monetary policy has changed substantially. In the period prior to January 1999 the exchange rates followed a crawling peg regime (fixed exchange rate regime) and devaluated around 7% per year. Therefore, international shocks had to be absorbed mainly by interest rates, which increased substantially in the events of the Asian and Russian crises. However, in mid-January 1999 the exchange rate suffered a large devaluation and the Brazilian government decided to let the exchange rate float and implement an Inflation Targeting Regime. The main idea of the Inflation Targeting regime was to build a monetary policy framework which reacted to inflation expectations (forward-looking). The commitment to a pre-announced inflation targeting would work as a coordinator of market expectations, which by its turn would generate a more stable inflation environment.

### 5. Long-range dependence in the term structure of Brazilian interest rates

This section presents results for testing for long-range dependence in interest rates for different maturities. Table 1 shows Hurst exponents estimated using both DFA and GHE methods. We estimate these Hurst exponents using the entire sample and also constructing two sub-samples. The differences between monetary policy regimes are striking, with Hurst exponents above 0.5 for all maturities in the period before the implementation of the inflation targeting regime and the float of the exchange rate and below 0.5 for maturities up to 6 months after the implementation of this regime. However, changes in 1-month

Table 1

This table presents Hurst exponents for the GHE and DFA methods for the full sample period, and the periods before and after the implementation of the Inflation Targeting framework for monetary policy and float of the exchange rate. Standard errors for the difference in Hurst exponents were estimated as the average of standard errors in both pre- and post-Inflation Targeting periods

| Maturity (months)                      | DFA   | Std. error | GHE   | Std. error |
|--|-------|------------|-------|------------|
| Panel A: Full sample                   |       |            |       |            |
| 1                                      | 0.565 | 0.013      | 0.551 | 0.019      |
| 3                                      | 0.541 | 0.015      | 0.506 | 0.023      |
| 6                                      | 0.540 | 0.015      | 0.510 | 0.022      |
| 12                                     | 0.545 | 0.015      | 0.517 | 0.022      |
| Panel B: Pre-Inflation Targeting       |       |            |       |            |
| 1                                      | 0.593 | 0.022      | 0.571 | 0.017      |
| 3                                      | 0.544 | 0.021      | 0.509 | 0.025      |
| 6                                      | 0.540 | 0.020      | 0.520 | 0.029      |
| 12                                     | 0.522 | 0.019      | 0.511 | 0.032      |
| Panel C: Post-Inflation Targeting      |       |            |       |            |
| 1                                      | 0.446 | 0.028      | 0.440 | 0.012      |
| 3                                      | 0.436 | 0.015      | 0.448 | 0.010      |
| 6                                      | 0.460 | 0.012      | 0.468 | 0.011      |
| 12                                     | 0.511 | 0.011      | 0.511 | 0.009      |
| Panel D: Difference in Hurst exponents |       |            |       |            |
| 1                                      | 0.148 | 0.025      | 0.132 | 0.014      |
| 3                                      | 0.108 | 0.018      | 0.061 | 0.018      |
| 6                                      | 0.079 | 0.016      | 0.052 | 0.020      |
| 12                                     | 0.011 | 0.015      | 0.000 | 0.020      |

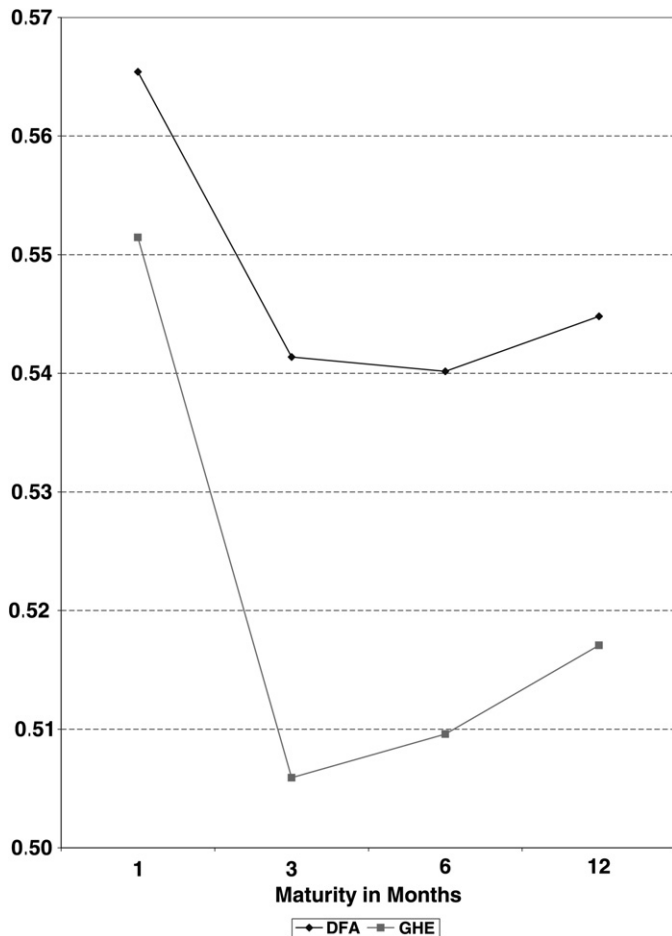


Fig. 1. Hurst exponents for yields with different maturities using DFA and GHE for the full sample.

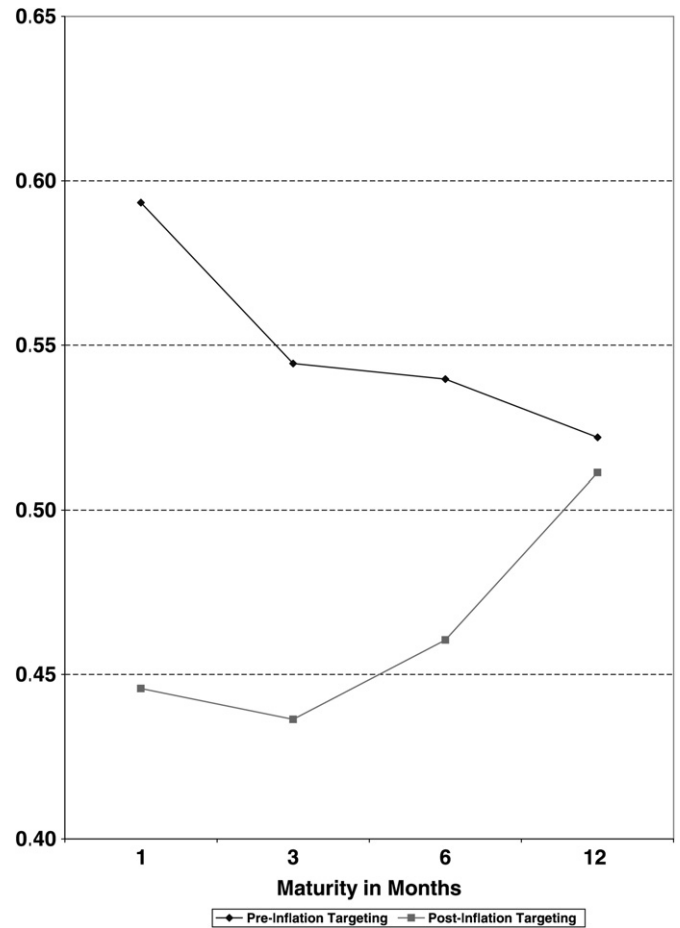


Fig. 2. Hurst exponents for yields with different maturities using DFA for the periods before and after the implementation of the Inflation Targeting framework and float of the exchange rate.

interest rates were substantial, and robust to the methodology employed to estimate Hurst exponents.

Fig. 1 presents Hurst exponents for the entire sample, using both the DFA and GHE methodology. These Hurst exponents are decreasing but the difference in Hurst exponents is small. However when we compare Hurst exponents across monetary regimes the pattern changes dramatically. Figs. 2 and 3 present Hurst exponents for two different monetary regimes, using the DFA and GHE methods.

Two main conclusions emerge from these empirical results. Hurst exponents show a substantial break in the dynamics of persistence in Brazilian interest rates, specially for short-term maturities. Second, the period before the implementation of the Inflation Targeting Regime is characterized by a downward slope in the Term Structure of Hurst exponents, while the period after the implementation with an upward slope. 1 year maturity interest rates do not present any evidence of a structural break, which suggests that studying the term structure of interest rates is worthwhile.

It is worth noting that short-term interest rates present anti-persistent behavior in the period after the implementation of the Inflation Targeting regime and the float of the exchange rate. Our interpretation for this phenomenon is that with the

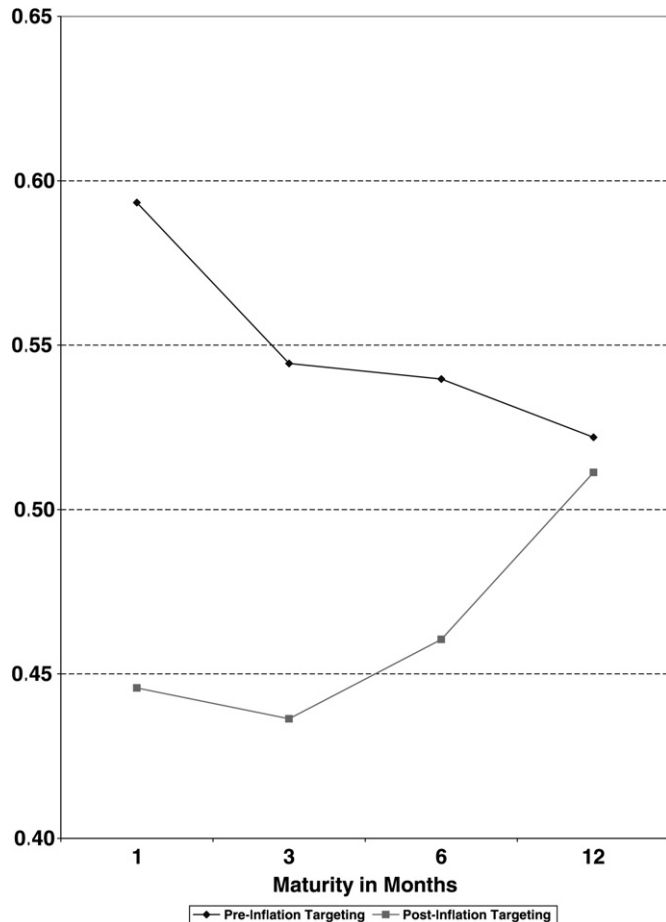


Fig. 3. Hurst exponents for yields with different maturities using GHE for the periods before and after the implementation of the Inflation Targeting framework and float of the exchange rate.

abandonment of the fixed exchange rate regime, shocks to the Brazilian economy could be absorbed by the exchange rate and not only by interest rates as before. Therefore, we should expect a reduction in the persistence pattern of interest rates due to the increase in the degrees of freedom of economic policy. Furthermore, domestic interest rates were quite high if compared to other countries. With the success of the Inflation Targeting framework in anchoring inflation expectations we should expect interest rates to display mean-reverting patterns (anti-persistence) and reduce to lower levels.

## 6. Conclusions

In this Letter we have shown empirical evidence of long-range dependence in the Brazilian term structure of interest

rates. We show that Hurst exponents change substantially with the implementation of the Inflation Targeting Regime in 1999, reducing substantially interest rates persistence afterwards.

The economic intuition for the empirical results is that the previous monetary policy cycles that occurred within the period before the implementation of the Inflation Targeting regime have had a substantial change. This is true because within an Inflation Targeting regime the exchange rate is floating and therefore, the exchange rate may absorb, at least partially, external shocks. When exchange rates are fixed external shocks must be absorbed by changes in domestic interest rates, and therefore, one should expect interest rates to show more persistence.

This phenomenon is particularly true in our study, because structural changes in interest rates were more pronounced in short-term interest rates, with very little changes in 1 year maturity interest rates (considered long-term interest rates in Brazil).

Our results show that methods derived from econophysics may be able to help explain dynamics of important macroeconomic and financial variables such as interest rates. Further research could focus on a variety of countries that have adopted different monetary regimes and studying changes in persistence across regimes.

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