Journal Pre-proofs

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PII:	S1042-4431(21)00080-9
DOI:	https://doi.org/10.1016/j.intfin.2021.101361
Reference:	INTFIN 101361
To appear in:	*Journal of International Financial Markets, Institutions & Money*
Received Date:	12 June 2020
Revised Date:	4 May 2021
Accepted Date:	11 May 2021

Please cite this article as: N. Diniz Maganini, A.A. Rasheed, H. Hua Sheng, Exchange Rate Regimes and Price Efficiency: Empirical Examination of the Impact of Financial Crisis, *Journal of International Financial Markets, Institutions & Money* (2021), doi: https://doi.org/10.1016/j.intfin.2021.101361

Exchange Rate Regimes and Price Efficiency: Empirical Examination of the Impact of Financial Crisis

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*<u>**Acknowledgements**</u>

We are grateful for the financial assistance and support of the Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP), through process nº 2018 / 17477-8.

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Highlights

- Currencies under Free Float regime show greater price efficiency than currencies under Managed Float regimes.
- Currencies following the Free Float exchange regime experienced significantly greater deterioration in their price efficiency after the subprime crisis than currencies under Managed Float regimes.
- The efficiency of the currencies of the Free Float countries did not fully recover even a decade after the financial crisis.
- The analysis is based on a sample that includes all major economies in the world over a 15-year period and the results are thus more generalizable than prior studies that have focused on a much smaller set of countries.

Abstract

We analyze how different currency regimes influence the price efficiency of exchange rates. Based on an analysis of a sample of 20 exchange rates (covering 39 countries) over a 15-year period using MF-DFA (Multifractal Detrended Fluctuation Analysis), we find that currencies of countries following a Free Float regime show greater price efficiency than currencies of countries following a Managed Float regime. We also examined the impact of the financial crisis of 2008-09 on the price efficiency of these currencies. Our results suggest that currencies following the Free Float exchange regime experienced significantly greater deterioration in their price efficiency than currencies under Managed Float regimes. Even more interestingly, the efficiency of the currencies of the Free Float countries have not fully recovered even a decade after the crisis.

Key words: *Market Efficiency, Foreign Exchange Rate, Multifractal Theory, Financial Crisis*

1. Introduction

One of the foundational theories of modern finance is the efficient market hypothesis (Fama, 1970). Based on the degree to which available information is reflected in security prices, efficient market hypothesis (EMH) classifies market efficiency into three forms: weak, semi-strong, and strong. The trading of a financial asset is considered efficient in the weak form if market prices fully reflect the available information. A number of studies have attempted to empirically verify the extent to which markets are efficient (Fama & French, 1988; Lo & Mackinlay, 1988; Cheung & Coutts, 2001; Kim & Shamsuddin, 2008). Although such studies have mostly focused on the efficiency of stock markets, there have also been attempts to test the efficiency of other markets such as foreign exchange markets (Liu and He, 1991; Belaire-Franch & Opong, 2005; Stosic, et al., 2016), cryptocurrency markets (Al-Yahyaee, Mensi, & Yoon, 2018; Silva Filho, Maganini, & Almeida, 2018), oil markets (Arshad, Rizvi, Haroon, Mehmood & Gong, 2020), and gold markets (Ntim, English, Nwachukwu, & Wang, 2015).

Our focus in this paper is the analysis of the weak form of efficiency of foreign exchange markets. Understanding the behavior of exchange rate returns is of considerable interest to academics, trading professionals, and regulators. While academics seek to understand asset return behaviors over time, traders and investors are often interested in identifying market inefficiencies that produce exploitable patterns for abnormal returns. Regulators, unlike investors, are interested in improving the informational efficiency of the securities market in which exchange rates are negotiated (Belaire-Franch & Opong, 2005).

In an efficient market, foreign exchange prices are expected to reflect all available information so that abnormal profits from arbitrage are either reduced or quickly eliminated (Levich, 1985). Exchange rates play an important role in determining the dynamics of countries' stock and bond markets (Pavlova & Rigobon, 2007). It is particularly important for central banks to monitor exchange rates and ensure their price efficiency to prevent profit opportunities through arbitrage.

A number of prior empirical studies have examined the market efficiency of the exchange rates of different countries (Baillie & Bollerslev, 1989; Oh, Kim & Eom, 2007; Stosic, et al., 2016). While these studies have provided us with many insights about the efficiency of exchange rate markets, we are still far from having a clear understanding of the efficiency differences across countries for a number of reasons. First, many of the prior studies have focused on a specific country or a small group of countries in their examination of market efficiency. Second, many studies only examine whether or not a country's exchange rate is efficient over a given period of time without providing an explanation of the observed efficiency or lack thereof. Third, methodological approaches used in prior studies do not often allow us to compare efficiencies across countries. Therefore, in order to develop a deeper understanding of the price efficiency of exchange markets, one will need to examine a large number of countries and systematically relate the observed differences in their market efficiencies to underlying differences in the economic characteristics of the countries.

Countries differ in terms of the exchange rate regimes that they follow. The International Monetary Fund has identified nine different types of currency regimes. At one extreme are countries that follow a fixed exchange rate. At the other extreme are countries that follow a free floating regime wherein exchange rates are entirely set by the market. A large number of countries follow a managed float system where the currency is allowed to fluctuate within a band based on market forces, but governments may intervene when the currency trades outside that band. This paper analyzes the efficiency of exchange rate prices against the US dollar of countries that follow the Free Floating or Managed Floating regimes. Most of the leading nations in the world fall within these two categories.

Even when countries normally follow a free floating regime, there are extreme situations when a government may feel the need to intervene. One such event in recent times has been the global financial crisis of 2008. Often referred to as the sub-prime crisis, this was a period when the U.S. economy was rocked by a crisis of unprecedented proportions which subsequently spread to most other countries as well. In such situations, governments intervene to avoid excessive variations in currency prices. However, any such intervention and the possibility of future interventions may fundamentally affect the behavior of currency prices in ways that persist for extended periods of time. Therefore, in this paper we also examine how the financial crisis affected the efficiency of exchange rates. We compare the efficiencies of both free and managed float currencies before and after the financial crisis and examine how each of these types of currency systems recovered their efficiency after the crisis.

We conduct our analysis of efficiency differences of currency markets using Multifractal Detrended Fluctuation Analysis (MF-DFA), a method originally developed in econophysics (Matia, Ashkenazy, & Stanley, 2003; Wang, Liu, & Gu, 2009). The use of MF-DFA to assess price efficiency has been gaining greater acceptance in Finance research in recent years (Zunino et al., 2008; Al-Yahyaee, Mensi, & Yoon, 2018). Given that the majority of financial time series exhibit nonlinear scaling functions (Batten, Kinateder, & Wagner, 2014), the use of methodologies such as MF-DFA can provide insights that traditional methods may not be able to do.

Our paper makes the following contributions to the literature on exchange rates. First, by including most major currencies in the world, we are able to make inferences with a high degree of generalizability. Second, by systematically comparing free floating and managed-floating currencies, we are able to identify major systematic differences between these two prominent currency regimes. Third, we make a methodological contribution by demonstrating the applicability of multifractal analysis to study the complex dynamics of exchange rates in the long run. More specifically, MFDFA allows comparison of the efficiencies of different currencies which is difficult to do with other methodological approaches.

The remainder of this paper is organized as follows. The next section reviews the prior literature on the efficiency of exchange markets and develops our hypotheses. We then present our data and methodology. This is followed by the results of our analysis. Finally, we provide a discussion of our results and our conclusions.

2. Literature Review and Hypotheses

2.1 Market Efficiency and Exchange Rate Regimes

Ever since Fama (1970) presented the efficient market hypothesis (EMH), numerous attempts have been made by researchers to empirically verify if markets are indeed efficient in the weak form. Most of these studies have focused on the equity markets of different countries, primarily to improve the predictability of stock prices to optimize portfolios and perform dynamic resource allocation.

Although the foreign exchange market is the largest and most liquid financial market in the world (Stosic et al., 2016), there have been relatively few empirical examinations of its efficiency. Compared to stocks and fixed income investments, the foreign exchange market is characterized by a lower level of transparency (Melvin & Taylor, 2009). However, developing a better understanding of the efficiency of exchange markets is important because currency fluctuations have far-reaching effects on economic activities and outcomes such as imports, exports, prices, inflation, financial crisis, and economic growth (Hooper & Kohlhagen, 1978; Kandil, Berument & Dincer, 2007), in addition to playing an important role in determining the dynamics of the stock market (Pavlova & Rigobon, 2007).

Weak form market efficiency in currency markets means that exchange rates should behave randomly. That is, market participants cannot make abnormal gains based on past prices of a currency. The empirical test of weak form efficiency concentrates on the spot exchange rates to verify if a currency behaves as random walk (Wickcremasinghe & Kim, 2008). The semi-strong form of efficiency holds that exchange rate movements would reflect all publicly available information such as interest rates, inflation, and trade balance. The strong form extends both the weak and semi-strong forms by adding inside information.

Much of the vast body of prior research on exchange rates deal with issues not related to price efficiency such as the impact of government decisions regarding the exchange regime and its relationship with economic, political and market factors in a country (Rogoff, Husain, Mody, Brooks & Oomes, 2004; Tsangarides, 2012; Ghosh, Ostry & Qureshi, 2014). In recent years, however, there have been several attempts to verify the EMH in currency markets. While most of these studies have tested for the weak form of EMH, a small number of studies have attempted to test the semi-strong form (Mazzoli & Barducci, 2009). Early research on exchange rate efficiency analyzed the efficiency of the foreign exchange markets of developed countries. Using the unit root test, Meese and Kenneth (1982) found that the exchange rates of Germany, Switzerland and Canada showed signs of efficiency during the period between 1976 and 1981. Similarly, Baillie and Bollerslev (1989) found that exchange rates of United Kingdom, Germany, France, Italy, Switzerland, Japan, and Canada were not efficient between 1980 and 1985, also using the unit root test.

Liu and He (1991), using the Variance Ratio Test (VR) method, found that the Deutsche Mark, Japanese Yen, British Pound, Canadian Dollar and the French Franc were not efficient between August 1974 and March 1989. Another finding along these lines using the same method was that, between 1999 and 2002, exchange rates of Australia, New Zealand, Norway, Switzerland, Sweden and the United States were efficient, and that the currencies of Canada and Singapore were inefficient (Belaire-Franch & Opong, 2005). The Asian market was also investigated in the same way and it was found that the exchange rates of Japan, South Korea, and the Philippines have low levels of efficiency whereas Taiwan's exchange rate is inefficient

(Chiang, Lee, Su, & Tzou, 2010). Lee, Pan and Liu (2001) analyzed the exchange rates of nine Asian countries, and found that the daily prices mostly followed a random walk between the years 1988 and 1995.

Recent studies of price efficiency of exchange rates have begun to explore the implications of governmental monetary policy and the type of exchange regime adopted by countries. For the Asian market, it was found that the exchange rates of countries adopting the Free Floating regime are more efficient than those who adopt the Managed Floating regime (Ahmad, Rhee, & Wong, 2012). However, it is difficult to draw generalizations based on these studies because they are mostly limited to a small group of countries in a specific continent or a specific group of countries, but do not address systematic variations between different types of exchange regimes. Belaire-Franch and Opong (2005), for example, studied daily data between 1999 and 2002 on exchange rates of Australia, New Zealand, Canada, Norway, Singapore, Switzerland, Sweden and the United States, and found Canada and Singapore as inefficient. Oh, Kim and Eom (2007) examined 17 exchange rates before and after the Asian crisis (periods of 1984-1998 and 1999-2004) and found that European and North American markets are more efficient than African and Asian markets, except Japan.

Researchers have recently started applying new and innovative methodologies to study the efficiency of exchange rates. Through the analysis of 21 exchange rates, Richards (2000), for example, found that they had multifractal properties. Norouzzadeh and Rahmani (2006) found, using the MF-DFA (Multifractal Detrended Fluctuation Analysis) method, that that the Iranian exchange rate has a high degree of multifractality and therefore was inefficient. Batten, Kinateder and Wagner (2014) used the MMAR model (Modified version of the Multifractal model of Asset Returns) and found that the MMAR approach is superior to the more conventional GARCH model. Batten and Ellis (1996) examined if the US$/Japanese Yen exchange rate exhibited a fractal structure using the rescaled range (*R*/*S*) technique and found that there were time and memory effects that were arbitrable. Similarly, Stošić et al. (2015) used the entropy method to study the exchange rates of eight countries (Brazil, Australia, Malaysia, New Zealand, South Korea, Sweden, Taiwan and Thailand) during the period in which these countries used managed exchange rates and after they changed to free floating exchange rate regime, and concluded that free floating exchange rates are more efficient. Yang, Shao, Shao, and Stanley (2019) investigated the efficiency of the Euro to Swiss Franc exchange rate based on ultrahigh-frequency returns. Using the DMA/DFA method, they found that the Swiss National Bank´s interventions might reduce the efficiency of the market. Kallianiotis (2017) represents an initial attempt to test the semi-strong form of market efficiency using the random walk hypothesis, the composite efficiency hypothesis, and exchange rate expectations based on anticipated and unanticipated events. The study found that the dollar/euro market is efficient, but neither the dollar/pound nor yen/dollar are. Mazzoli and Barducci (2009) tested for the semi-strong form of market efficiency for the Euro-dollar exchange rate using monthly data and did not find support for EMH. A novel feature of their study was incorporating time dependent process of propagation of information.

A review of the prior studies on the efficiency of exchange rates leads to four conclusions. First, the efficiency of exchange rates varies across countries. Second, despite these observed differences, we do not have any clear explanations for these differences. Most studies, even when they undertake comparative investigations, only report whether a country's exchange rate is efficient or not without attempting to offer explanations for the observed differences. Third, based on prior studies it is difficult for us to conclude whether the behavior of exchange rates of a given currency regime is superior or inferior compared to another regime in terms of price efficiency. Finally, our ability to make comparisons across studies is somewhat limited because of the differences in the methodologies applied and the time periods studied.

Managed Floating and Free Floating exchange rates regimes are more common than fixed exchange rates and, as economies mature, their exchange rate flexibility increases. For countries at a relatively early stage of development and financial integration, fixed or relatively tight regimes appear to offer some anti-inflation credibility gains without compromising the country's growth objectives. As the country develops economically and institutionally, there appears to be considerable benefits from more flexible regimes, and for developed countries, more flexible exchange rates seem to offer higher growth (Rogoff, Husain, Mody, Brooks, & Oomes, 2004).

Once a country adopts fluctuating exchange rates, managed or not, concerns about its volatility arise as excessive levels of volatility can hinder growth, especially in countries with underdeveloped capital markets (Aghion, Bacchetta, Ranciere, & Rogoff, 2009). These higher levels of volatility may be associated with the lower efficiency of the behavior of exchange rates. Prior literature, in general, suggests that intervention by central banks reduces the price efficiency of exchange rates (Yilmaz, 2003). Given that free floating currency regimes are subject to far less intervention by central banks than the currencies of countries that follow the managed float regime, we hypothesize that

H1: *Countries that adopt the Free Floating exchange regime exhibit higher price efficiency than countries that adopt the Managed Floating exchange rate.*

2.2 Exchange Rates in Times of Financial Crisis

Most market economies periodically go through periods of financial crisis. During financial crises, the volatility of returns becomes excessively high. Such periods are also characterized by a fall in asset values which affects the solvency of a large number of banks and their ability to honor commitments to their depositors (Allen & Gale, 2004; Corsetti, Pericoli & Sbracia, 2005). In addition to increased volatility, global financial crises impact negatively on the informational efficiency of foreign exchange markets due to uncertainties in the economic environment caused by recessions, rising inflation and falling economic growth (Hooper & Kohlhagen, 1978; Kandil, Berument & Dincer, 2007). In today's interdependent global economy, financial crisis in one country also tends to affect the economies of other countries, often snowballing into a global financial crisis.

Even though a crisis has negative impact on the exchange rate price efficiency, the severity of its effect depends on two systemic factors. The first is the liquidity of the market. Prior empirical research suggests that higher liquidity is associated with greater efficiency. Oh, Kim, and Eom (2007), for example, in their study of 17 exchange rates using the entropy method found that more liquid markets, such as European and North American markets, are more efficient than the ones with lower liquidity, such as African and Asian countries except Japan. They also studied the price efficiencies before and after the Asian crisis and found that the efficiency of markets with lower liquidity such as Asian foreign exchange markets improved significantly after the Asian currency crisis. Another study on the effects of financial crisis found that exchange markets with higher liquidity and larger trading volume recovered faster from a crisis than markets with lower liquidity and smaller trading volume (Stosic, et al., 2016).

The second factor affecting the impact of financial crisis on price efficiency is the exchange rate regime adopted by the countries. In terms of loss of output and growth resilience, during a crisis, growth for countries that adopted a fixed exchange rate regime was no different from countries that adopted a floating exchange rate regime. For the recovery period (2010-2011), prior research shows that countries that follow fixed exchange rate regimes had a slower recovery (Tsangarides, 2012). Another insight obtained from empirical analysis of exchange rates in times of financial crisis is that fixed regimes lead to some vulnerabilities in terms of external imbalances and thus are more susceptible to growth crisis. Therefore, it has been suggested that emerging markets should adopt intermediate exchange rate or Free Floating regimes because these are less prone to financial crises (Ghosh, Ostry, & Qureshi, 2014). More specifically, regarding the behavior of exchange rates during financial crisis, it has been found that during the Asian and subprime crises, countries that adopted Free Floating regimes experienced greater volatility than countries that adopted Managed Float regimes (Ahmad, Rhee, & Wong, 2012).

Even governments that follow free floating regimes have been found to take preventive measures to avoid excessive variations in its currency prices during periods of financial crisis. One such measure may be an intervention in its exchange rate, sometimes in order to defend a falling currency and sometimes to limit appreciation pressure (Weber & Wyplosz, 2009). According to Levy-Yeyati and Sturzenegger (2016), all countries, except Canada, intervened in some way on their exchange rates in 2008 in response to the subprime crisis. Under normal economic conditions, the foreign exchange rates of countries with Free Floating regimes tend to be more efficient because they leave their exchange rates free of interventions, and subject to market forces. During times of financial crisis, sharp movements in exchange rates have the potential to render borrowers and sometimes even governments insolvent (Chamon, et al, 2019) and therefore governments tend to intervene to control volatility (Fratzscher, et al., 2019). It is likely that these currencies will experience a greater negative impact from governmental interventions than currencies under Managed Float regimes. This is because for Free Floating regimes, the intervention will be an external disturbance that will interfere with its regular dynamics, while for Managed Floating regimes such disturbances are more usual. That is, for them it is more a matter of magnitude of intervention than a departure from normal practice. Therefore, we hypothesize that:

H2: *Countries that follow a Free Floating exchange rate regime will experience a greater negative impact on the efficiency of the prices of their currencies than countries that follow a Managed Floating regime.*

3. Data and Methodology

3.1 Data

The data used in this study is the daily exchange rates time series of all countries that used Managed Floating or Free Floating regimes in relation to the US dollar from 2012 until 2019. We collected the daily exchange rates time series from Thomson Reuters database. Information on the exchange regimes of these countries was obtained from International Monetary Fund annual reports. Countries that follow Free Floating regimes had an average nominal GDP of more than U$ 270 billion in 2018. Countries that follow Managed Float showed much greater variance with several countries with very low GDP levels. We excluded countries with a nominal GDP of less than US$ 250 billion in 2018 to ensure that the two groups are comparable.

According to the International Monetary Fund's Annual Report on Exchange Arrangements and Exchange Restrictions (2019) there are 9 classifications of currency regimes: Currency board, Conventional peg, Stabilized arrangement, Crawling peg, Crawl-like arrangement, Pegged exchange rate within horizontal bands, Other managed arrangement, Floating and Free Floating. The price efficiency of Floating and Free Floating regimes is the focus of our research as most of the large economies of the world fall within one of these two categories.

Floating, named "Managed Floating" in this paper, is defined by Annual Report on Exchange Arrangements and Exchange Restrictions (2019) as:

> *A floating exchange rate is largely market determined, without an ascertainable or predictable path for the rate. In particular, an exchange rate that satisfies the statistical criteria for a stabilized or a crawl-like arrangement is classified as such unless it is clear that the stability of the exchange rate is not the result of official actions. Foreign exchange market intervention may be either direct or indirect and serves to moderate the rate of change and prevent undue fluctuations in the exchange rate, but policies targeting a specific level of the exchange rate are incompatible with floating. Indicators for managing the rate are broadly judgmental (e.g., balance of payments position, international reserves, parallel market developments). Floating arrangements may exhibit more or less exchange rate volatility, depending on the size of the shocks affecting the economy.*

Free Floating is defined by the Annual Report on Exchange Arrangements and Exchange Restrictions (2019) as:

> *A floating exchange rate can be classified as free floating if intervention occurs only exceptionally and aims to address disorderly market conditions and if the authorities have provided information or data confirming that intervention has been limited to at most three instances in the previous six months, each lasting no more than three business days. If the information or data required are not available to the IMF staff, the arrangement is classified as floating. Detailed data on intervention or official foreign exchange transactions will not be requested routinely of member countries—only when other information available to the staff is not sufficient to resolve uncertainties about the appropriate classification.*

Because all exchange rates were compared to the US dollar, we did not include US $ in our sample. Moreover, since all countries in the euro zone have only one exchange rate, they were considered as one entity, namely, the "Euro Zone". Thus, the database consisted of 20 exchange rates, 10 considered as Managed Floating and 10 as Free Floating. Table 1 identifies all countries that have a Managed Floating or Free Floating classification since the year 2012, according to International Monetary Fund reports, and have achieved nominal GDP of more than US$ 250 billion in 2018.

Insert Table 1 about here

The analysis was done with log returns of daily prices of the exchange rates listed in Table 1. Because we are analyzing price efficiencies before and after the financial crisis, we considered the period from January 2000 to January 2007 as the period before the financial crisis and the period from January 2009 to December 2016 as after the crisis. In addition, we also assessed the efficiency over the 15 year period between May 2004 and April 2019.

3.2 Methodology

Financial time series are functionally complex systems which have a predominantly non-linear temporal dynamics, dynamics which is also termed chaotic. It follows that they may be especially sensitive to external disturbances, making forecasting of future behaviors extremely difficult. Therefore, in recent years, researchers have started applying non-linear tools to analyze these behaviors. One such tool that has gained increasing popularity is Multifractal Detrended Fluctuation Analysis (MF-DFA) which allows us to measure the efficiency of market prices returns in the long term. MF-DFA has been used in recent years to measure the efficiency of stock markets (Zunino et al., 2008; Onali & Goddard, 2009; Wang, Liu & Gu, 2009; Liu, Wang & Wan, 2010; Stavroyiannis, Makris & Nikolaidis, 2010; Horta, Lagoa & Martins, 2014; Jin, 2016; Al-Yahyaee, Mensi & Yoon, 2018; Tiwari, Aye & Gupta, 2019; Maganini, Silva Filho & Lima, 2018).

The generalized multifractal DFA (MF-DFA) procedure consists of six steps as proposed by Kantelhardt et al. (2002). The first three steps are essentially identical to the conventional DFA analysis. Let us suppose that x_k is a series of length N, and that this series is of compact support, i. e. $x_k = 0$ for an insignificant fraction of the values only.

Step 1: Determine the profile:

$$Y(i) \equiv \sum_{k=1}^{i}\left[x_k - \langle x \rangle\right], \qquad i = 1,\ldots, N. \qquad \textbf{(1)}$$

Subtraction of the mean $\langle x \rangle$ is not compulsory, since it would be eliminated by the later detrending in the third step.

Step 2: Divide the profile $Y(i)$ into $N_s \equiv int(N/s)$ non-overlapping segments of equal length s. Since the length N of the series is often not a multiple of the considered time scale s, a short part at the end of the profile may be left over. In order to avoid disregarding this part of the series, the same procedure is repeated starting from the opposite end. Thus, $2N_s$ segments are obtained.

Step 3: Calculate the local trend for each of the $2N_s$ segments by a least-square fit of the series. Then determine the variance.

$$F^2(s,v) \equiv \frac{1}{s}\sum_{i=1}^{s}\{Y[(v-1)s+i] - y_v(i)\}^2 \qquad \textbf{(2)}$$

For each segment v, $v = 1, \ldots, N_s$ and

$$F^2(s,v) \equiv \frac{1}{s}\sum_{i=1}^{s}\{Y[N-(v-N_s)s+i]-y_v(i)\}^2 \qquad \textbf{(3)}$$

For $v = N_s + 1, \ldots, 2N_s$. Here, $y_v(i)$ is the fitting polynomial in segment v.

Thus, a comparison of the results for different orders of DFA allows one to estimate the polynomial trend in the time series.

Step 4: Average over all segments to obtain the qth order fluctuation function

$$F_q(s) \equiv \left\{\frac{1}{2N_s}\sum_{v=1}^{2N_s}\left[F^2(s,v)\right]^{q/2}\right\}^{1/q} \qquad \textbf{(4)}$$

Where, in general, the index variable q can take any real value except zero. For $q = 2$, the analysis is identical to the standard DFA procedure. Steps 2 to 4 are repeated for several time scales s. For financial time series, the most common practice is to repeat these steps for values of q from -10 to 10 (Wang, Liu & Gu, 2009; Zunino et al., 2008, Maganini, Filho & Lima, 2018).

Step 5: Determine the scaling behavior of the fluctuation functions by analyzing log-log plots $F_q(s)$ versus s for each value of q.

$$F_q(s) \sim s^{h(q)} \qquad \textbf{(5)}$$

The function h(q) is the generalized Hurst exponent.

Step 6: Eq. (5) can be written as $F_q(s) = AS^{h(q)}$. After taking logarithms of both sides, we get

$$\log F_q(s) = \log A + h(q)\log s \qquad \textbf{(6)}$$

From Eq (6), the value of the Generalized Hurst exponent h(q) can be estimated.

For monofractal time series characterized by a single exponent over all times scales, h(q) is independent of q. For multifractal time series, h(q) varies with q. The different scaling of small and large fluctuation will yield a significant dependence of h(q) on q. Therefore, for positive value of q, h(q) describes the scaling behavior of the segments with large fluctuations;

and for negative q values, the scaling exponent h(q) describes the scaling behavior of segments with small fluctuations.

Another way to confirm multifractality in a time series is through multifractal spectrum analysis, which is based on the following relationship between Generalized Hurst exponent h(q) obtained from MF-DFA and the Renyi exponent $\tau(q)$:

$$\tau(q) = qh(q) - 1 \qquad \textbf{(7)}$$

Then, through a Legendre transform, we get

$$\alpha = h(q) + qh'(q) \qquad \textbf{(8)}$$

and

$$f(\alpha) = q[\alpha - h(q)] + 1 \qquad \textbf{(9)}$$

From Equation 6 we can define the multifractality degree as:

$$\Delta hq = \max[h(q)] - \min[h(q)] \qquad \textbf{(10)}$$

From Equation 8 we can define the intermittency degree as:

$$\Delta\alpha = \max[\alpha] - \min[\alpha] \qquad \textbf{(11)}$$

The lower the value of the Δhq and Δα parameters, higher the efficiency of the time series (Zunino et al., 2008; Wang, Liu & Gu, 2009; Sensoy & Tabak, 2016).

4. Results

The results of our MF-DFA analysis of the efficiency of the currencies following Free Floating and Managed Float regimes for the 15-year period from 2004 to 2019 are presented in Table 2. It provides the values of Δhq (Generalized Hurst exponent) and Δα (Intermittency Degree) for Managed Float and Free floating countries. From the results in Table 2, it can be observed that, among the 10 exchange rates with Managed Floating regime, only 4 have values of Δhq lower than 0.4, while for countries with Free Floating regime all 10 exchange rates have values of Δhq lower than 0.4, indicating a higher price efficiency for Free Floating exchange rates. Further, Managed Float currencies show greater variance in their efficiency compared to

Free Float currencies. It should be noted that the Δhq of the countries with Floating exchange rate regimes vary between 0.2372 and 0.7113 and the Δα range between 0.3791 and 0.8787, while for Free Floating countries this variation for Δhq is between 0.2086 and 0.3503 and the Δα range between 0.3527 and 0.5394. We can observe the values of Δhq and Δα are greater for Managed Floating countries. This indicates that the behavior of Managed Floating currencies is less efficient than of Free Floating currencies.

Table 2 also shows that the standard deviations for the time series that follows the managed floating regime (0.1588 for Δhq and 0.1704 for Δα) is much greater than the standard deviations of free floating time series (0.0455 for Δhq and 0.0573 for Δα). A t-test comparing the means shows that both Δhq and Δα values are significantly lower for Free Floating currencies than for Managed Float currencies ($p < 0.0093$ for Δhq and $p < 0.0113$ for Δα). These results provide clear support for H1. Our results corroborate and complement Ahmad, Rhee and Wong (2012) who found Free Floating countries to be more efficient than Managed Floating countries in an Asian sample.

Insert Table 2 about here

The second part of our analysis involved the comparison of efficiency changes that occurred as a result of the financial crisis. For this purpose, we considered the period from January 2000 to January 2007 as the period before the financial crisis and the period from January 2009 to December 2016 as after the crisis. The results in Table 3 show that before the subprime crisis, the Δhq of countries with the Managed Floating regime were between 0.3101 and 0.8271 (average 0.5237), while for the period after the financial crisis the Δhq were between 0.1889 and 0.6764 (average 0.3931). Among countries with Free Floating exchange regime, the degree of efficiency before the crisis was between 0.1716 and 0.3014 (average 0.2361) and after the crisis was between 0.3059 and 0.4317 (average 0.3563). Similarly, the degree of intermittency, Δα, for Managed Floating countries before the financial crisis was between 0.4453 and 1.021 (average 0.6886), while for the period after the financial crisis it was between 0.3111 and 0.8775 (average 0.5536). Among countries with Free Floating exchange regime, the Δα before the crisis were between 0.2782 and 0.4533 (average 0.3685) and after the crisis were between 0.4464 and 0.6196 (average 0.5167). That is, countries that follow Free Float regimes experienced substantial declines in efficiency in the period after the financial crisis compared to the period before the crisis. We also find that free float currencies had greater efficiency and lower variability in their efficiencies compared to currencies following the Managed Float system.

The results of our comparison between the periods before and after the financial crisis provide some interesting results. For countries adopting the Free Floating exchange rate policy, the level of efficiency shows a clear deterioration subsequent to the financial crisis compared to the pre-crisis period (between 31.25% for Mexico and 77.14% for Sweden). It is important to note that, even with this worsening, Free Floating exchange rates are still more efficient than Managed Floating countries. For countries that have a Managed Floating exchange rate regime, the levels of exchange rate efficiency after the financial crisis have improved for Brazil, Colombia, India, Philippines, South Africa, Thailand and Turkey. On the other hand, it worsened for Indonesia, Israel and Korea.

Insert Table 3 about here

Figure 1 provides a graphical comparison of the efficiencies before and after the financial crisis. While Panel A provided mixed evidence regarding Managed Float currencies, Panel B clearly indicates that Free Floating currencies showed declining efficiencies across the board. Taken together, these results show that the financial crisis had a clear negative impact on the efficiency of the currencies of the free float countries and somewhat divergent impacts on the efficiencies of managed float countries. Thus, the results provide clear support for our H2 which stated that countries that follow a Free Floating exchange rate regime will experience a greater negative impact on the efficiency of the prices of their currencies than countries that follow a Managed Floating regime.

Insert Figure 1 about here

A graphical representation of our results is provided in Figures 2 to 5. Figure 2 presents the generalized Hurst Exponents h(q) for different values of q for the analyzed exchange rate series for a period of 15 years. Panels A and B show Free Floating and Managed Float currencies respectively. For better visualization we group the countries in groups of five in each graph. It can be seen from Figure 2 that the values of the generalized Hurst exponents are decreasing as q increases, indicating the multifractal behavior of the series. The lower the Δhq, the more efficient is the time series (Zunino et al., 2008; Wang, Liu & Gu, 2009; Sensoy & Tabak, 2016; Silva Filho, Maganini & Almeida, 2018).

Figures 3 shows a similar comparison of the multifractal spectrum of the analyzed series. These plots identify the maximum parameter α and the minimum parameter α of the samples. The width (difference between the maximum and minimum parameters) is one of the indicators of multifractal behavior of the data as well as the efficiency of the financial time series (Sensoy & Tabak, 2016). The greater the width of the parabola, the greater the degree of multifractality of a financial time series, i.e., the less efficient is the financial time series. A comparison of Panels A and B clearly show that the price series of Managed Float currencies have wider parabola than those of the Free Floating currencies.

Figures 4 and 5 present visual comparisons of changes in the values of Δhq and Δα before and after the financial crisis. Panels A and B provide the direct contrast between Free floating and Managed Float currencies. Figure 4 shows a noticeable increase in Δhq for free float currencies after the financial crisis, indicating a decline in efficiency. For Managed Float currencies the pattern is more ambiguous. Figure 5 which presents the comparison for the intermittency degree clearly shows the decline in the efficiencies of free float countries as evidenced by the increase in the width of the parabola. On the other hand, the width of the parabola for Managed Float currencies have shrunk, indicating that they experienced improvements in efficiency.

Insert Figure 2 about here

Insert Figure 3 about here

Insert Figure 4 about here

Insert Figure 5 about here

5. Discussion and Conclusion

Efficiency of exchange rates is an important concern for active traders as well as for government policy makers. Attempts at explaining the factors that lead to greater efficiency are still in their initial stages and at this point we have only a limited understanding of what causes a currency to be efficient or not. Similarly, prior literature offers only a limited understanding of the factors that cause fluctuation in the efficiency of the exchange rate of a currency. In this paper, we offer the currency regime of the country as an explanation of its efficiency. Further, we suggest that exogenous shocks like a major financial crisis may have differential impacts on the efficiency of a currency based on the exchange rate regime that it follows.

The results of our study indicate that countries that follow a Managed Float regime have lower efficiency in the behavior of the prices of their exchange rates compared to countries that follow the Free Floating exchange regime. Further, the efficiencies of the exchange rates of Managed Floating countries show greater variability than Free Float countries in terms of both the indicators of efficiency, namely, Δhq and $\Delta\alpha$.

It was also found that the financial crisis had a greater negative impact on the price efficiency of countries adopting the Free Floating exchange regime than that of countries following the Managed Float regime. A possible cause for the worsening of the exchange rate efficiencies of the Free Floating countries is that all these countries intervened in their exchange rates during the year 2008 (Levy-Yeyati & Sturzenegger, 2016). The fact that interventions have a greater impact on Free Floating exchange regimes may be because interventions occur more frequently in Managed Floating countries and these interventions are already incorporated in the prices of these exchange rates, whereas for countries that adopt the Free Floating regime this fact is not embedded in prices and, when there is intervention, the efficiency tends to worsen by a more significant degree. However, it is important to note that the behavior of Free Floating exchange rates still remains more efficient than Managed Floating. Our results are consistent with the findings of Yilmaz (2003) who found a negative relationship between exchange rate efficiency and government interventions. The improvements in the efficiencies of the Managed Float currencies, although modest, is a somewhat surprising result. Although we do not have a clear explanation for this, it is possible that governmental intervention in response to a major financial crisis was viewed more favorably by the markets than interventions without a strong rationale.

One of the more interesting observations about the price behavior of currencies based on our results is that the impact of a financial crisis may be longer lasting than previously assumed. The price efficiency of the exchange rates of countries following the Free Float regime not only experienced significant reductions (between 31.25% and 77.14%) after the subprime crisis, but even after a decade, their efficiency levels have not recovered to the pre-crisis levels. For Managed Floating countries the results are more ambiguous with some countries showing improvement while others show deterioration. While governments may have no choice but to intervene during a major financial crisis, such intervention may have a lasting effect on the price efficiency of their currencies and may take a long time to get back to the pre-crisis levels.

Our study represents an initial effort to provide an explanation for the differences in the price efficiency levels of different currencies. While we considered two major currency regimes for our analysis of the impact of currency regimes on price efficiency, it is important to consider additional currency regimes as well to develop a more comprehensive understanding of the relationship between different currency systems and exchange rate efficiency. Similarly, although our findings support the assertion that governmental interference may have a negative effect on the price efficiency of currencies, further studies are required to evaluate the implications of different types of governmental interventions as well as the magnitude of those interventions. Another promising avenue of future research may be the examination of the sources of multifractality in different currency regimes. Finally, our methodological approach restricts us to testing the weak form of EMH, but not the semi-strong or strong forms.

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Table 1.

Countries and currencies sampled for analysis

Free Floating		Managed Floating	
Country	**Currency**	**Country**	**Currency**
Australia	AUD	**Brazil**	BRL
Canada	CAD	**Colombia**	COP
Chile	CLP	**India**	INR
Euro Zone	EUR	**Indonesia**	IDR
Japan	JPY	**Israel**	ILS
Mexico	MXN	**Korea**	KRW
Norway	NOK	**Philippines**	PHP
Poland	PLN	**South Africa**	ZAR
Sweden	SEK	**Thailand**	THB
United Kingdom	GBP	**Turkey**	TRY

Table 2.

Degrees of multifractality and intermittency of currencies based on daily quotes for the 15-year period (from May 2004 to April 2019).

Managed Floating exchange rate regime countries				Free Floating exchange rate regime countries			
Country	**Currency**	**Δhq**	**Δα**	**Country**	**Currency**	**Δhq**	**Δα**
Brazil	BRL	0.3646	0.5370	**Australia**	AUD	0.2961	0.4542
Colombia	COP	0.5481	0.7297	**Canada**	CAD	0.2973	0.4578
India	INR	0.4191	0.5861	**Chile**	CLP	0.3240	0.4985
Indonesia	IDR	0.6330	0.8193	**Euro Zone**	EUR	0.3503	0.5394
Israel	ILS	0.3245	0.4772	**Japan**	JPY	0.3052	0.4447
Korea	KRW	0.4161	0.5753	**Mexico**	MXN	0.3418	0.5110
Philippines	PHP	0.2372	0.3791	**Norway**	NOK	0.2086	0.3527
South Africa	ZAR	0.2448	0.3961	**Poland**	PLN	0.3228	0.4988
Thailand	THB	0.7113	0.8787	**Sweden**	SEK	0.2505	0.4009
Turkey	TRY	0.5122	0.6948	**United Kingdom**	GBP	0.2478	0.4098
Average		**0.4411**	**0.6073**	**Average**		**0.2944**	**0.4568**
Std Dev.		**0.1588**	**0.1704**	**Std Dev.**		**0.0455**	**0.0573**

Table 3.

Degree of multifractality and intermittency of daily returns of the currencies, before (from January 2000 to January 2007) and after (from January 2009 to December 2016) a financial crisis.

Country	Currency	Δhq (before)	Δα (before)	Δhq (after)	Δα (after)	Change in Δhq
Countries with "Managed Floating" exchange rate regime						
Brazil	BRL	0.4234	0.5831	0.4076	0.5879	+3.73%
Colombia	COP	0.5271	0.7011	0.4705	0.6305	+10.74%
India	INR	0.6762	0.8454	0.3347	0.4852	+50.5%
Indonesia	IDR	0.5427	0.7168	0.6764	0.8775	-24.64%
Israel	ILS	0.3101	0.4453	0.3566	0.5207	-15%
Korea	KRW	0.3173	0.4577	0.4664	0.6310	-47%
Philippines	PHP	0.6078	0.7837	0.2970	0.4485	+51.13%
South Africa	ZAR	0.3199	0.4685	0.1889	0.3111	+40.95%
Thailand	THB	0.8271	1.021	0.3731	0.5229	+54.9%
Turkey	TRY	0.6852	0.8631	0.3593	0.5203	+47.56%
Average		**0.5237**	**0.6886**	**0.3931**	**0.5536**	
Std. Dev.		**0.1791**	**0.1965**	**0.1287**	**0.1474**	
Countries with "Free Floating" exchange rate regime						
Country	Currency	Δhq (before)	Δα (before)	Δhq (after)	Δα (after)	Change in Δhq
Australia	AUD	0.2144	0.3340	0.3460	0.5007	-61.38%
Canada	CAD	0.1716	0.2782	0.3059	0.4464	-78.26%
Chile	CLP	0.2821	0.4188	0.4317	0.6196	-53.03%
Euro Zone	EUR	0.2370	0.3711	0.3146	0.4713	-32.74%
Japan	JPY	0.2387	0.3774	0.3133	0.4532	-31.25%
Mexico	MXN	0.3014	0.4533	0.3971	0.5577	-31.75%
Norway	NOK	0.1987	0.3109	0.3187	0.4804	-60.39%
Poland	PLN	0.2680	0.4179	0.3944	0.5508	-47.16%
Sweden	SEK	0.1925	0.3155	0.3410	0.5104	-77.14%
United Kingdom	GBP	0.2567	0.4082	0.4004	0.5763	-55.98%
Average		**0.2361**	**0.3685**	**0.3563**	**0.5167**	
Std. Dev.		**0.0418**	**0.0571**	**0.0455**	**0.0574**	

* Euro Zone consists of Austria, Belgium, Cyprus, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Portugal, Slovak Republic, Slovenia and Spain.

Figure 1.

Multifractal degrees (Δh) before (from January 2000 to January 2007) and after (from January 2009 to December 2016) a financial crisis.

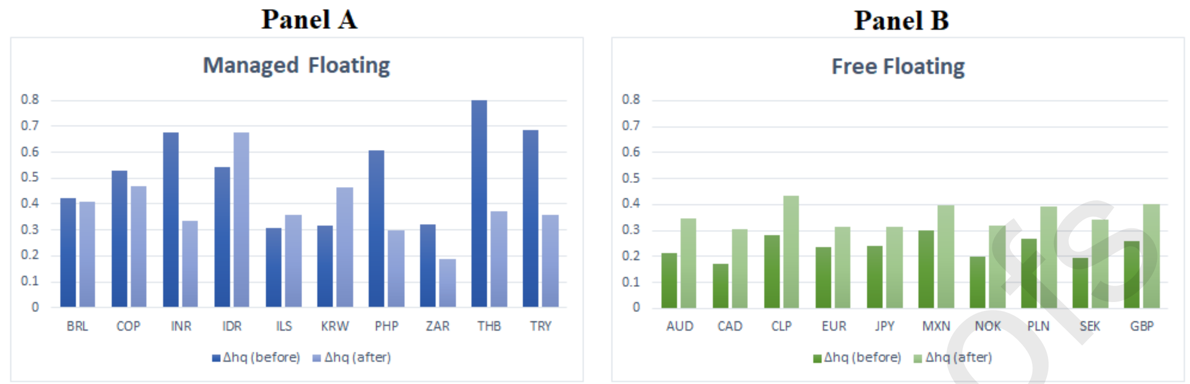


Figure 2.

Generalized Hurst exponents of daily exchange rate returns for 15 years (from May 2004 to April 2019).

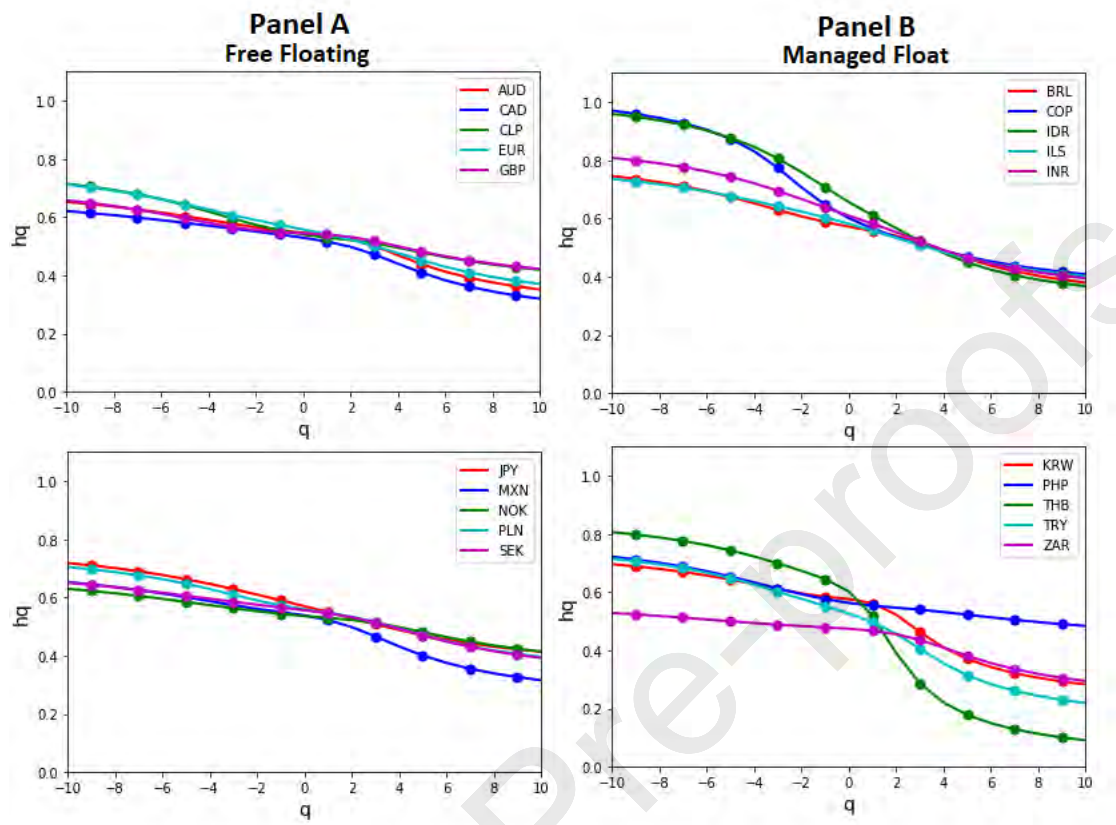


Figure 3.

Multifractal Spectrum of daily exchange rate returns for 15 years (from May2004 to April 2019).

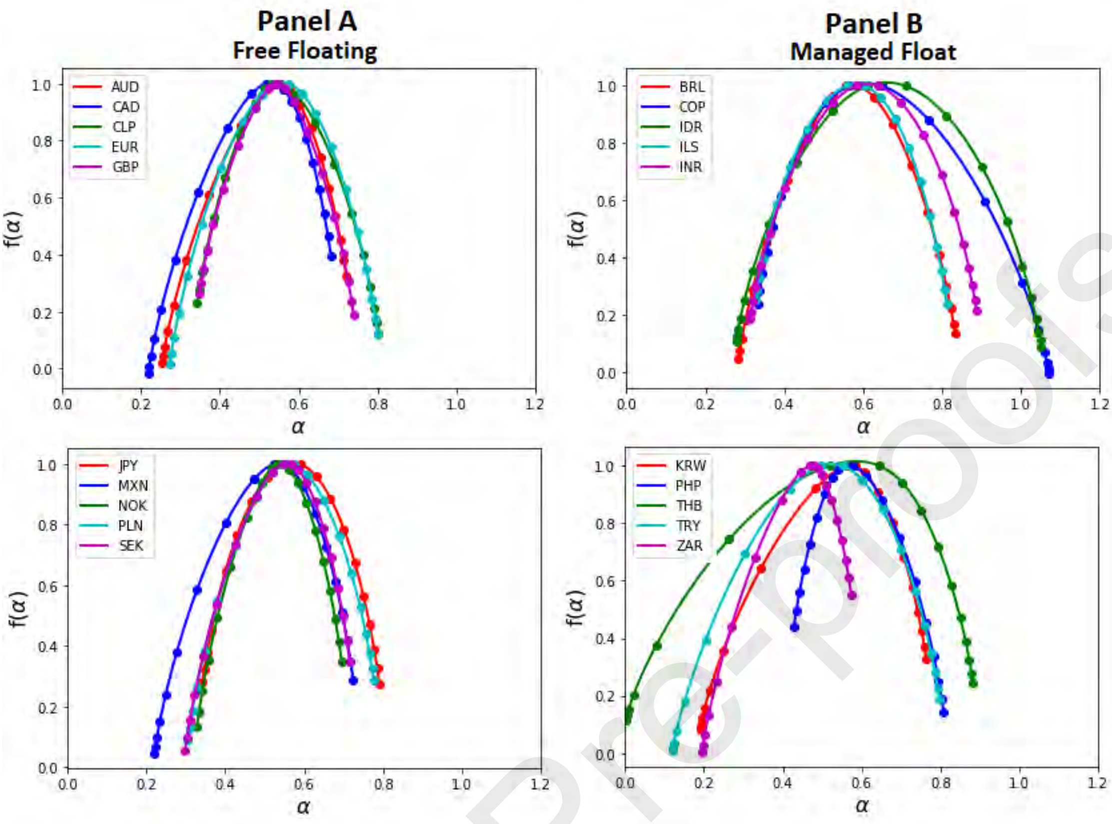


Figure 4.

Generalized Hurst exponents of daily exchange rate returns before (from January 2000 to January 2007) and after (from January 2009 to December 2016) the subprime crisis.

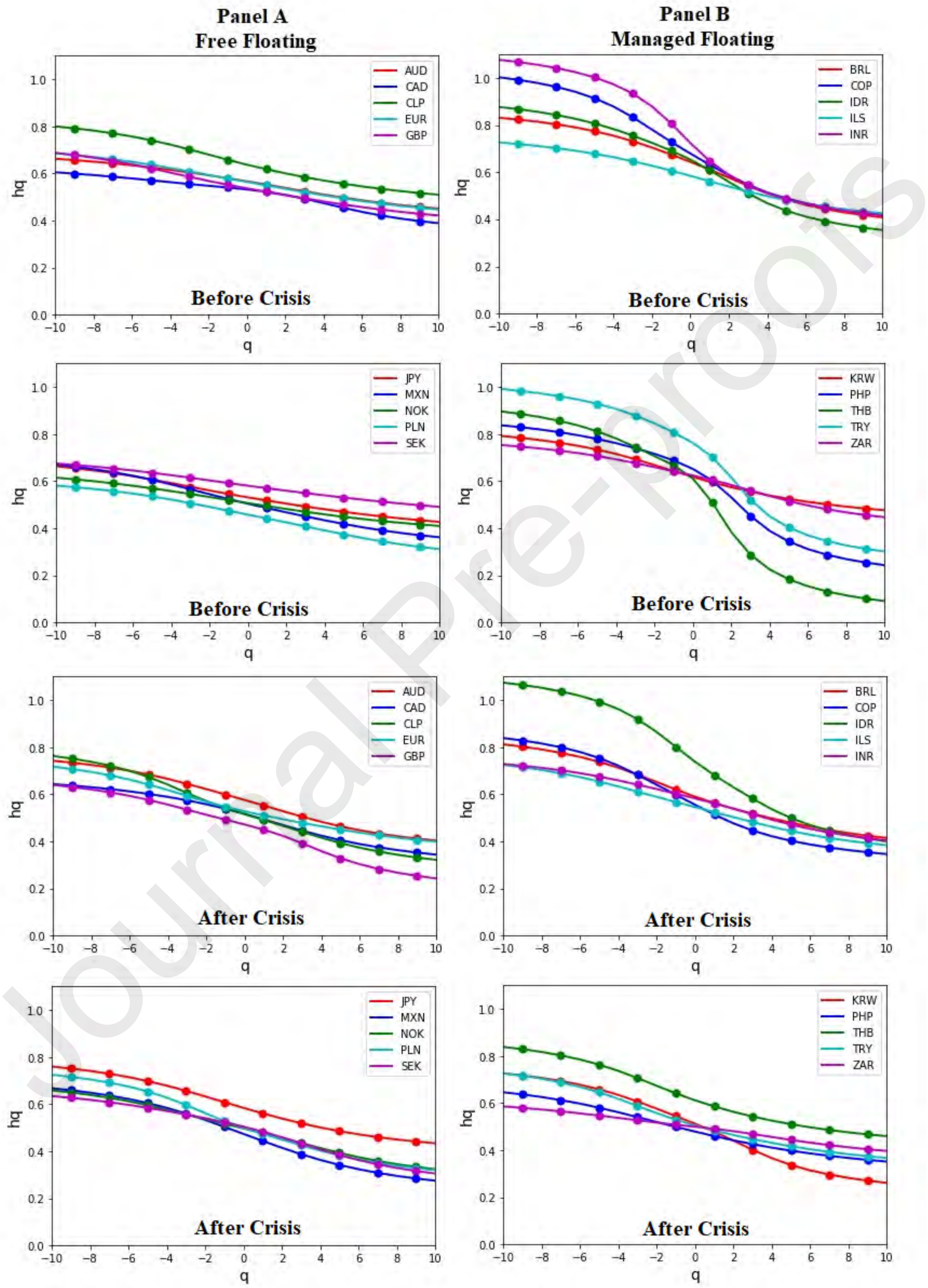
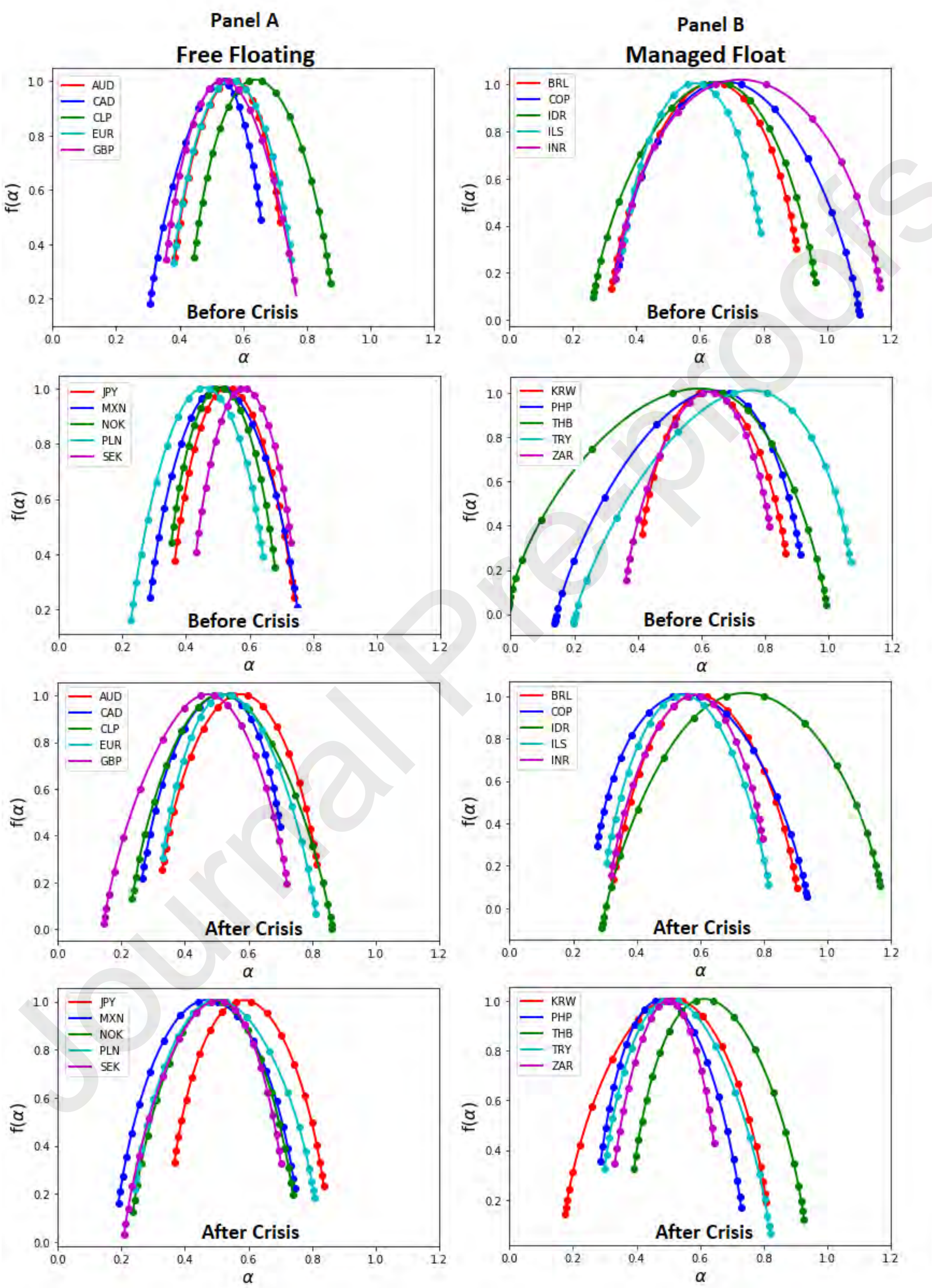


Figure 5.

Multifractal Spectrum of daily exchange rate returns, before (from January 2000 to January 2007) and after (from January 2009 to December 2016) the subprime crisis.



Author Statement

Exchange Rate Regimes and Price Efficiency: Empirical Examination of the Impact of Financial Crisis

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