A study of Chinese market efficiency, Shanghai versus Shenzhen: Evidence based on multifractional models

Pierre R. Bertrand[1], Marie-Eliette Dury[2], and Bing Xiao[3]

[1] Université Clermont Auvergne, CNRS, LAPSCO and LMBP,
F-63000 Clermont-Ferrand, France
pierre.bertrand@uca.fr
[2] Université Clermont Auvergne, CNRS, CERDI, F-63000 Clermont-Ferrand, France
m-eliette.dury@uca.fr
[3] Université Clermont Auvergne, IUT Aurillac, CLERMA EA 38 49, France
bing.xiao@uca.fr

Abstract. The Chinese equity market is one of the emerging equity markets which offers an opportunity for international diversification, as a emerging markets, the Chinese stock markets are not mature. Since the 1990s, the reforms in regulations as well as in the attitudes of regulators have rendered the stock market more efficient. The progressive reform process of the stock market has improved the functioning of capital markets and implemented market-based mechanisms. China's stocks pricing mechanism has been pushed toward a more market-oriented approach, in such cases, we expect an alteration in anomalies in the Chinese stock market. In this paper, we examine the daily data from the Shanghai A-share market, and Shenzhen A-share market over the 2006-2019 period. It would seem that in the Chinese stock market, the seasonal anomalies persist. But at the same time, by employing the Hurst exponent analysis, we find that the Chinese stock markets had a trend of becoming more and more efficient after the reform in October 2011.

Keywords. Stock markets, Seasonal anomalies, Efficient market hypothesis, Hurst exponent, Multifractional Brownian motion.

M.S.C. classification. 62M45, 65C05, 68T05.
J.E.L. classification. C52, C53, C58, G1, G10, G12, G14, G17.

Mathematical Methods in Economics and Finance – m²ef
Vol. 13/14, No. 1, 2018/2019

1 Introduction

The Chinese stock markets have drawn a lot of attention from international investors for their fast growth and China's economic development. Because of its low correlation with other stock markets and high average returns, the Chinese stock markets seem to offer an opportunity for international diversification. But, as any emerging market, the Chinese stock markets are inefficient [19]. However, the reforms in regulations as well as in the attitudes of regulators have rendered the stock market more efficient. One of the most important reforms was CSRC (China Securities Regulatory Commission) reform in October 2011. Thanks to this reform, Shanghai Stock Exchange (SSE) and Shenzhen Stock Exchange (SZSE) have reached sensible improvements. These observations lead the authors to determine how well the reforms improve the efficiency in the Chinese stock market. This study focuses on the Shanghai stock market and the Shenzhen stock market. We divided the whole series (Shenzhen A-shares and Shanghai A-shares) into two sub-series at the criterion of the date of 2011 reform. The evolution of the Hurst index indicate that Shenzhen stock market and Shanghai stock market were becoming more and more efficient after the reform.

The structure of this article is as follows. Section 1 provides a brief overview of the existing literature about the reforms in the Chinese stock market. Data and methodology are described in section 2 which recalls the Hurst exponent analysis method. Section 3 displays the results of this study.

2 The anomalies and the reforms in Chinese stock market

The anomalies generate a large amount of interest in academic circles. If it were possible to show that investment strategy based on the anomalies is capable of systematically beating the market, the efficient market theory would be faulty. In this section, we present the seasonal anomalies in China. And we detail the reforms in regulations, especially; we focus on the 2011 reform.

2.1 The seasonal anomalies in Chinese stock market

One of the anomalies in Chinese stock markets is the seasonal effect. For example, if there is a negative day-of-the-week effect, the rational arbitragers could sell stocks short in the morning and buy them back the next day. Such trading activity would eventually result in the disappearance of the effect. A considerable body of literature has been produced that documents anomalies in stock returns. A day of the week effect was detected in the U.S. market by different researchers [10], [14], [17], [33]. These studies document a negative mean return for Monday and a positive mean return for Friday. The month-of-the-year effect was found by [16]. They found a positive January effect and a negative December effect. *"Sell in May and Go Away"* effect means that stocks have higher returns in the November–April period than the May–October one [23]. This effect is significant in 35 out of 108 countries. The Sell in May effect exists in the Chinese stock

market [18], [22]. This effect can be explained by bank credit [18]. A simple trading strategy, which based on the effect, is shown to outperform the buy-and-hold strategy and can protect investors from dramatic losses during large recession. Their findings provide insights to those international investors who are interested in the Chinese stock market. Outside of the *"Red May"* effect, a positive February effect, a positive June effect and a negative December effect are found in the Chinese A-share stock markets [18].

This being said, a monthly effect, during certain periods, does not necessarily imply a weak of efficiency. For analysis of seasonality, we have to analyze if investment strategy based on seasonality is capable of systematically beating the market. According to academic research, only in a few countries can investors take advantage of month-of-the-year regularities when investing in the stock market [13], [37].

In this paper, we focus exclusively on the day-of-the-week effect. There are evidence of weak efficiency in the form of predictability of returns on the basis of their own past values as well as systematic day-of-the-week and holiday effects [20]. The evidence regarding day-of-the-week effects is rather mixed as conclusions from various studies seem to depend heavily on the particular choice of sample period. Using daily returns, the seasonal patterns of the Chinese stock markets are at odds with the majority of findings for other stock exchanges around the world [30]. They found a positive Thursday returns. In contrast with their studies, the evidence of negative Tuesday returns in the Chinese stock market is detected in 2006.

2.2 The reforms in Chinese stock market

China has owed its expansion to decades of economic reforms, the openness if its markets to attract international capital. But historically, the Chinese stock market has been described as having a low information environment [15]. China's stock market was characterized by a high level of information asymmetry, low quantity and quality of information disclosed by listed companies, and low governance transparency. Although the Chinese stock markets have played an increasing role in China's economy, they have remained highly segmented [38]. Chinese investors are described in the academic literature as shortsighted and speculative and very oriented to the short run and to heavy trading [34].

Stock price is a suitable indicator of a company's financial performance and the stock market represents a major channel for investment and financing for Chinese companies [36]. To render the stock market more efficient, the Chinese government had enhanced the legislative and regulatory framework and revised Chinese accounting standards several times in an attempt to improve the poor information environment. In 1993, the State Council issued a decision on financial system reforms that incorporated a strategy for interest rate liberalization. The objective was to encourage banks to lend to small and medium-sized enterprises, which tended to receive fewer loans than larger firms that were seen to be more creditworthy. In the early 2000s, the authorities began a process of

gradually liberalizing interest rates on loans that culminated in the removal of nearly all such restrictions in 2013.

One of the most important reforms was price limit reform on December 16th, 1996. Before the reform, stock prices could fluctuate at any magnitude and were easily driven up by some institutional investors. After the reform, the variation range of stock price during a business day was limited to be no more than 10% and some special treated stocks 5%. The stock prices were no longer easily driven up by the institutional investors. The China Securities Regulatory Commission (CSRC), enhanced the supervision of, and increased the penalty for speculators from 2001 onwards.

By analyzing the degree of multifractality of Shenzhen stock market, [35] concluded that the Shenzhen stock market became more and more efficient over time, especially after a price-limited reform. However, the effects on the short-term market efficiency were minor.

Realizing the problems with the split share structure, the Chinese government began to reduce the proportion of state ownership by selling state-owned shares into the market in June 2001. Li investigates the impact of China's 2001-2003 share reforms on the investable stocks' asset-pricing mechanisms [26]. He shows that the reforms have caused the size and dividend effects to attenuate, and those reforms have practical implications for investors in China's investable stocks.

The corporate governance in China is adapting as the country's economy transform. A important part of this change is via state-owned enterprises (SOEs). To help solve the fundamental governance problems, the Chinese government initiated a split share structure reform program in April 2005 (SOE reform). The aim of the reform is to convert non-tradable shares into tradable shares. The non-tradable shareholders gain from the reform as their shares become tradable. This increases liquidity and enables controlling shareholders to sell at market prices. Gong and Marsden found that significant positive profits are most common in the pre-SOE reform period but not in the post-reform period, which suggests that the SOE reform played an important role in improving efficiency in both Stock Exchanges [19]. In recent period, the authorities have increased the pace of its reform of the financial industry. As a result, SOEs have been consolidating and the bringing the managers to run them more efficiently.

Administrative Measures on Information Disclosure (AMID) by listed Companies were introduced in 2007. The reforms were expected to have implications for the information environment of the Chinese A-share market. The empirical evidence suggests that the increase in the level of information disclosure of the Chinese A-share sample can be attributed to the 2007 AMID reforms. Gong & Marsden suggested that AMID reforms have resulted in an increase in the level of information disclosure by Chinese listed A-shares to the market [19]. This greater level of information disclosure should improve market fairness for all investors and reduce any information asymmetry between informed and uninformed investors.

Reform of CSRC in October 2011. In October 2011, China Securities Regulatory Commission (CSRC), the Chinese market regulator, announced measures to reform the Chinese stock market. The reform project would first of all allow the country's financial markets to mature. The stock market in China is barely twenty years old. Many companies, including banks, have entered after 2005. The next step would be to liberalize the Chinese stock market, effectively mobilize Chinese savings, restructure and modernize Chinese industries, and develop innovation. Lastly, it would be a question of promoting sustainable development.

Lower transaction costs. Firstly, China Securities Regulatory Commission (CSRC), decided to reduce transaction fees of the Shanghai and Shenzhen Stock Exchange. The fees would amount to 0.0087% of the trading volume in the two stock markets compared to 0.011% previously for the Shanghai Stock Exchange and 0.0122% for the Shenzhen Stock Exchange.

IPO system. China's IPO system (Initial Public Offering) is built in such a way that prices are constantly overvalued, serving the interests of newly introduced companies and their underwriters and damaging the interests of investors who end up suffering losses after a few days of transactions. In order to avoid such situations, the regulator asks Chinese companies to provide additional financial information when their price-to-earnings (PE) ratio is 25% higher than the industry average.

Withdrawal of the rating. The CSRC has also announced measures to strengthen the exit rules. The regulations in force had been found to be too lax and encouraging speculative behavior. To be withdrawn, the company had to record three consecutive years of net losses. Between 2001 and 2011, only 40 companies withdrew. Some companies accounted for non-recurring items in net income and used public institutions to post profits and avoid going out. The reform, which aims to delete the *"garbage equities"*, would consider eight new conditions to strengthen the requirements for delisting, including three consecutive years of operating income below 10 million yuan. Companies with net negative assets will no longer be able to remain listed.

Encouragement of incoming and outgoing flows. Another measure taken by the stock exchange authority was to increase QDII (Qualified Domestic Institutional Investor) quotas, licenses allowing domestic actors to invest abroad and QFII (Qualified Foreign Institutional Investor) quotas, licenses allowing foreign investors to buy shares listed on the domestic market. QFII quotas were extended to $80 billion, compared with $30 billion after the reform (distributed among 158 investors with institutions like the Korea Investment Corp or the Kuwait Investment Authority).

Beyond the expansion of quotas, the CSRC would seek to ease the conditions for obtaining a license to allow foreign investors to buy securities in the country.

The current rules require that an actor has at least $5 billion assets under management and has been in business for at least 5 years. The thresholds imposed on banks and brokerage firms are higher.

Accelerating financial innovation. Eleven proposals were made by the regulator to address the lack of differentiation between products perceived as an obstacle to the rise of the financial industry in China. Other developments were proposed, such as encouraging mergers and acquisitions between securities companies; promoting investor participation in the OTC market; adjustment of risk management systems, distribution of dividends, in particular by public companies; the possibility for pension funds to invest in the stock market.

Opening of the capital of brokerage firms to foreign operators. China has agreed to raise the threshold for foreign investors to hold the equity stake in domestic brokerage companies from 33% to 49%. This new rule should not really change the profile of the industry dominated by more than 100 local companies, and the interference with policy interests is important. However, it would be a significant step forward. The reforms previously discussed in this article must render the market efficient. We expect an alteration in seasonal anomalies in the Chinese stock market. According to Li and Lin [25], the implementation of the new pricing reform may potentially have affected the uncertainty of the Chinese stock market, particularly in relation to energy-intensive sectors. Peng show that the structural reforms facilitated business formation and led to a higher aggregate output [31].

3 Methodology

This section is organized as follows. First of all, we will present our sample as well as the methods used to return measurements. Then, we will define the Fractional Brownian motion and Multifractional Brownian motion.

3.1 Data and statistic descriptive

The Chinese stock market has a relatively short history, there are two stock exchanges operating independently in the China, the Shenzhen Stock Exchange and Shanghai Stock Exchange. Chinese stock markets separate foreign investors form domestic investors through dual classes of stocks. Individual shares are divided into two classes of shares: A-shares and B-shares. A-shares are available for domestic investors and B-shares are available for foreign investors. The Shenzhen Stock Exchange was established on April 11, 1991. At August 11, 2019, there were already 2175 listed companies in the Shenzhen Stock Exchange (SZSE) (www.szse.cn). The Shenzhen Composite (SZC) Index is a market-capitalization weighted index of stocks in the Shenzhen Stock Exchange which tracks the daily price movements of all the shares in the exchange. The index began on April

3, 1991, with a base price of 100. The current Shanghai Stock Exchange was re-established on November 26, 1990, At August 11, 2019, there were 1514 listed companies in the Shanghai Stock Exchange (SSE) (www.sse.com.cn). It is the world's 4th largest stock market by market capitalization at US $5.5 trillion as of April 2018.

Figure 1 shows the price series for the Shenzhen and the Shanghai Indexes, the requisite data is obtained from the Factset database.

Fig. 1. Price for DJ Shanghai Index and Shenzhen A Share Index in USD 2006 – 2019.

The stylized facts of the financial series are noted, we can see the price can be difficult to model directly. The trend is far from stationary since its mean level is not constant and rises over time. A standard procedure to model the logarithmic price return rather than prices themselves. The logarithm of the gross return $R_{\ell n}$ is given by:

$$R_{\ell n} = \ln\left(\frac{P_t}{P_{t-1}}\right) \tag{1}$$

where R_t denotes the rate of return at time t, P_t the price at time t, and P_{t-1} denotes the price just prior to the time t.

Academic research document a negative mean return for Monday and a positive mean return for Friday. The higher returns on a particular weekday are due to the higher risk assumed on that day: a higher standard deviation is associated with higher daily mean returns except Monday. French [13] hypothesized that the standard deviation for Monday returns should be the highest because a greater number of shocks can manifest themselves over the weekend break [13].

The model to estimate the day of the week effect given by the follow equation [30].

$$R_t = \alpha_0 + a_1 \cdot d_{1,t} + a_2 \cdot d_{2,t} + a_3 \cdot d_{3,t} + a_4 \cdot d_{4,t} + e_t \tag{2}$$

where R_t is the return on day t and $d_{i,t}$ are dummy variables that takes the value of one for a given day of the week and is zero otherwise.

3.2 Unobserved components model

We approach our series of Shenzhen and Shanghai Indexes by using an unobserved components time series model (UCM) [18]. The model allows us to decompose the index I_t between three components given by:

$$I_t = \mu_t + \gamma_t + \varphi_t + \varepsilon_t \qquad \text{with} \quad \varepsilon_t \sim \mathcal{N}\Big(0,\, \sigma_\varepsilon^2\Big), \tag{3}$$

where μ_t, γ_t and ε_t represent trend, seasonal and irregular components respectively.

The trend and seasonal components are modeled by linear dynamic stochastic processes which depend on disturbances. They are formulated in a flexible way and can change over time rather than being deterministic. The quantity $\varphi_t$corresponds to a set of explanatory and dummy variables. The trend component is simply modeled as a random walk process according to the structure of our data:

$$\mu_{t+1} = \mu_t + \eta_t \qquad \text{with} \quad \eta_t \sim \mathcal{N}\Big(0,\, \sigma_\eta^2\Big), \tag{4}$$

where $\mathcal{N}\Big(0,\, \sigma^2\Big)$ refers to a normally independently distributed series with mean zero and variance σ^2. All models are estimated by using maximum likelihood.

3.3 The fractional Brownian motion and Multifractional Brownian motion

A constant Hurst exponent. Fractional Brownian motion (fBm) has been introduced in an abstract framework by Kolmogorov [24], then applied by Mandelbrot [28] for modelling stock prices. FBm is a Gaussian process, characterized by just one parameter, namely the Hurst index H. More precisely, we have the

Definition 1. *The fBm* $\{B_H(t),\ t \in \mathbb{R}\}$ *is the zero mean Gaussian process which covariance function is*

$$cov\big[B_H(s),\, B_H(t)\big] = \frac{\sigma^2}{2}\Big\{|s|^{2H} + |t|^{2H} - |t-s|^{2H}\Big\} \quad \textit{for all} \ \ (s,t) \in \mathbb{R}^2. \tag{5}$$

The Hurst index ranges in $(0, 1)$, it corresponds to roughness of the path which have critical Holder regularity $\alpha = H$, long memory properties when $H > 1/2$,

persistency of the increment when $H > 1/2$ or anti-persistency when $H < 1/2$. FBm admits different representations and can be also viewed as a Gaussian field depending both on the time t and the Hurst index H. For instance, the harmonisable representation of the fBm considered as a Gaussian field is given by

$$B(t,H) = \int_{\mathbb{R}} \frac{\left(e^{it\xi} - 1\right)}{|\xi|^{H+1/2}}\, dW(\xi), \quad \text{for all } \ t \in \mathbb{R}, \tag{6}$$

where $(t,H) \mapsto B(t,H) := B_H(t)$ is the fBm, and W is a complex valued Wiener measure such that $B(t,H)$ is real valued.

Different methods for estimating Hurst index have been proposed. In this paper, following [2], we use generalized quadratic variations (GQV) .

Modelling financial assets by fBm has been controversial since the 1960's. Indeed, mainstream finance prefer to model stock prices by martingales or semi-martingales, which have both a Hurst index $H = 1/2$. This is partly justify by the market efficiency hypothesis due to Fama [12]. On the other hand, behavorial finance has pointed that when $H > 1/2$ the prices are persistent which corresponds to over-confidence of the market, and when $H < 1/2$ the prices are anti-persistent which corresponds to under-confidence [7], [8], [9].

A time-varying Hurst exponent. However, fBm appeared as a to restrictive model in some applications. Mainly since just one parameter the Hurst index drives all properties. So [3] introduced the multifractional Brownian motion (mBm). MBm is a process where the constant Hurst index H has been replaced by a time-varying one $H(t)$, see [1]

Definition 2. *Let $(t,H) \longmapsto B(t,H)$ be the Gaussian field defined by (6). the multi-fractional Brownian motion can be defined by*

$$X(t) = B(t, H(t)). \tag{7}$$

Due to the time-varying Hurst index, stationarity of the increments does not hold anymore, therefore both long range dependency and structure of the increments are meaningless notions. For the mBm, only the roughness of the paths corresponds to the Hurst index $H(t)$, under some technical condition [1], [3].

Estimation of the Hurst index for fBm and mBm and statistical estimation of Hurst index. Let X be a fBm or a mBm. We observe one path of size n of the process X with mesh h_n, namely $\big(X(0), X(h_n), \ldots, X(nh_n)\big)$. For simplicity and without real restriction, we can assume that $h_n = 1/n$. We use quadratic variations to estimate the Hurst index. For a fBm with Hurst index H, we have

$$\mathbb{E}\left(|X\left(t+h_n\right) - X(t)|^2\right) = |h_n|^{2H}. \tag{8}$$

On the one hand, the stationarity of the increments of fBm allows us to estimate the variance by the empirical variance and to get a central limit theorem (CLT).

On the other hand, we can estimate the variance at M different meshes of time, that is $h_n, 2h_n, \ldots, Mh_n$; then linear regression of the logarithm of the empirical variance at those different meshes provides us an estimator of the Hurst index H. Moreover, a CLT is in force. For a mBm, the guiding idea is that a mBm behaves locally as a fBm [5], [6]. Therefore, we localise the estimation and we compute the empirical variance on a small vicinity of each time t, namely on

$$\mathcal{V}(t, \varepsilon_n) = \big\{ t_k \text{ such that } |t_k - t| \leq \varepsilon_n \big\},$$

where $\varepsilon_n \to 0$ and $\varepsilon_n / h_n \to \infty$ as $n \to \infty$.

4 Results

4.1 The seasonal variations

Table 1, Table 2 and Table 3 report the mean and standard deviation of daily stock returns for Shenzhen stock market and Shanghai stock market. For the whole period, returns have been positive. The lowest daily returns were found on Thursday. Table 2 and Table 3 report the mean return by day of week during the sub-period: before reform and after reform. The overall pattern is similar to that observed for the whole period; the Monday returns have been positive in each period. However, we do not find a Friday effect. Overall, the results are consistent with findings for other markets, except for the Friday effect. Table 1 and table 2 also report the standard deviation in daily returns, because it would be a source of insight into whether higher returns on a particular weekday are due to the higher risk assumed by an investor on that day. But we do not find that a higher standard deviation is associated with higher daily returns in our patterns.

Table 1. Daily percentage return for Shenzhen Stock Market and Shanghai Stock Market.

Periods	Whole period Oct. 2006-June 2019	Before reform Oct. 2006-Oct. 2011	After reform Oct. 2011-June 2019
Shenzhen A-Share	0.0005385 (3311) [0.0183579]	0.0008598 (1299) [0.0213315]	0.0003312 (2011) [0.0161563]
Shanghai A-Share	0.0004342 (3311) [0.0173038]	0.0006827 (1299) [0.0210908]	0.0002739 (2011) [0.0143443]

In each case, the first row shows the mean, in parenthesis there is the number of observations and in brackets ther is the standard deviation.

Table 2 and Table 3 show the descriptive statistics of the returns on the Shanghai and Shenzhen markets. Overall, we find a positive effect on Mondays

Table 2. Mean and standard deviation (S.D.) of daily percentage return Shenzhen Stock Market: day of the week during the whole period and sub-periods.

Periods	Whole period Oct. 2006-June 2019	Before reform Oct. 2006-Oct. 2011	After reform Oct. 2011-June 2019
Monday	0.0016151 (0.0007126) [0.023]	0.0029366 (0.0013192) [0.026]	0.0007604 (0.0008043) [0.345]
Tuesday	0.0004358 (0.000712) [0.541]	−0.0014660 (0.0013192) [0.267]	0.0016628 (0.0008033) [0.039]
Wednesday	0.00163156 (0.0016315) [0.022]	0.0031841 (0.0013192) [0.016]	0.0006274 (0.0008043) [0.435]
Thursday	−0.0014717 (0.0007126) [0.039]	−0.0007176 (0.0013192) [0.587]	−0.0019594 (0.0008043) [0.015]
Friday	0.0004820 (0.0007126) [0.499]	0.0003586 (0.0013192) [0.786]	0.0005617 (0.0008043) [0.485]

In each case, the first row shows the mean, in parenthesis there is the standard deviation and in brackets there is the p-value.

Table 3. Mean and standard deviation (S.D.) of daily percentage return Shanghai Stock Market: day of the week during the whole period and sub-periods.

Periods	Whole period Oct. 2006-June 2019	Before reform Oct. 2006-Oct. 2011	After reform Oct. 2011-June 2019
Monday	0.0014812 (0.0006718) [0.028]	0.0031709 (0.0013039) [0.015]	0.0003883 (0.0007142) [0.587]
Tuesday	−0.0000730 (0.00006713) [0.913]	−0.0019341 (0.0013039) [0.138]	0.0011277 (0.0007133) [0.114]
Wednesday	0.0011799 (0.0006718) [0.056]	0.0026333 (0.0013039) [0.044]	0.0002399 (0.0007142) [0.737]
Thursday	−0.0012839 (0.0006718) [0.056]	−0.0006759 (0.0013039) [0.604]	−0.0016771 (0.0007142) [0.019]
Friday	0.0008676 (0.0006718) [0.197]	0.0002165 (0.0013039) [0.868]	0.0012887 (0.0007142) [0.071]

The first row reports the mean, in parenthesis there is the standard deviation and in brackets there is the p-value.

over the whole period, however, this effect is significant before the reforms and attenuated afterwards.

Similarly, we observe a positive effect on Wednesdays, especially during the period before the reforms. We find that after the reforms, the returns on Wednesdays are not significantly different from zero for both markets. Regarding the negative effect on Thursdays, it is significant over the entire period, and also in both sub-periods. According to these descriptive statistics, the day of the week effect is attenuated in both markets after the reforms. Despite the persistence of the effect on Thursdays, markets seem to have become more efficient after the reforms.

In table 4 and table 5 below, we report results of the estimated coefficients of the different components of our unobserved components model. Column "Stochastic Trend" presents estimations for the basic stochastic component model. We find a significant Thursday effect by using the UCM model.

Table 4. Estimated coefficients for the unobserved components model Shenzhen stock market.

Shenzhen A-Share	Whole period Oct. 2006-June 2019	Before reform Oct. 2006-Oct. 2011	After reform Oct. 2011-June 2019
Monday		4.353253	3.744837
		(0.029)	(0.071)
Tuesday	−0.3012976		6.064087
	(0.839)		(0.003)
Wednesday	0.1779017	4.480039	3.948071
	(0.904)	(0.025)	(0.057)
Thursday	−3.7505100	0.5959548	
	(0.011)	(0.765)	
Friday	−1.421548	1.864696	3.013853
	(0.337)	(0.349)	(0.146)
Stochastic trend	−0.0201068	−0.0163247	−0.0220602
	(0.000)	(0.041)	(0.000)
C	4.729348	3.797283	1.170102
	(0.005)	(0.166)	(0.644)
AR(1)	1.017609	1.011019	1.01929
	(0.000)	(0.000)	(0.000)

Omitted values because of collinearity, in parenthesis there is the p-value.

For the Shenzhen market, we find that a Monday effect is significant, however, this effect is significant at 5% before the reforms (0.029 p-value), against only

10% after the reforms (0.071 p-value). Overall, we do not see a global influence of the Wednesday effect over the entire period, despite the presence of this effect in both sub-periods. As for the negative effect on Thursdays, we did have a negative effect over the whole period. This confirms our descriptive statistic that there is a negative effect on Thursdays.

Table 5. Estimated coefficients for the unobserved components model Shanghai stock market.

Shanghai A-Share	Whole period Oct. 2006-June 2019	Before reform Oct. 2006-Oct. 2011	After reform Oct. 2011-June 2019
Monday	0.2543936 (0.487)	0.2324647 (0.722)	0.1034498 (0.810)
Tuesday	−0.2264845 (0.536)	−1.4486600 (0.027)	0.3982914 (0.355)
Wednesday	0.1007897 (0.783)		
Thursday	−0.7116555 (0.052)	−0.9788643 (0.134)	−0.7040518 (0.102)
Friday		−0.7143252 (0.274)	0.2974653 (0.490)
Stochastic trend	−0.0152587 (0.003)	−0.0145036 (0.080)	−0.0161635 (0.011)
C	1.610027 (0.003)	2.429097 (0.007)	1.243403 (0.059)
AR(1)	1.011293 (0.000)	1.009372 (0.000)	1.012902 (0.000)

Omitted values because of collinearity, in parenthesis there is the p-value.

In the Shanghai market, the UCM model does not detect an effect on Mondays, regardless of the entire period taken into account or the sub-periods. As in the Shenzhen market, we detect an overall negative effect for Thursdays, although this effect is not significant over the sub- periods. For both stock markets, the regression results show that stochastic components and autoregressive components are significant, which confirms the quality of our model. An efficient market corresponds to rational investor and rational governors. The seasonality means the return series are not efficient, to confirm our intuition, we test for efficiency of Shanghai stocks index using multifractal models. We compute the Hurst exponent, and next we compare the Hurst component between the two periods.

4.2 Hurst exponent analysis

According to the descriptive statistical studies, it seems that in these two markets, the anomalous days of the week persist, for example in the Monday effect, the Wednesday effect and the Thursday effect, which means that there is a certain inefficiency in the two markets studied. However, some anomalies are mitigated after the reforms, or less significant than before the reforms. This suggests that there is an improvement in the degree of efficiency in these two markets. This impression is confirmed by the study of the Hurst index (Table 6), using the price series, we find that in the Shenzhen market, the Hurst index is 0.6549 before the reforms against 0.6216 after the reforms, a decrease of 0.0502. In the Shanghai market, we have seen the same trend, the Hurst index is 0.7116 before the reforms against 0.6735 after the reforms, a decrease of 0.0535. So the Hurst indexes moved closer to 0.50 after the reforms. The phenomenon of long-term memory persistence is therefore attenuated. This confirms our descriptive statistical study.

Table 6. Estimated piecewise constant Hurst index and decrease ratio of the Hurst exponent.

Hurst exponent	Oct. 2006–Oct. 2011	Oct. 2011–June 2019
H Shenzen	$H_{before} = 0.6549$	$H_{after} = 0.6216$
H Shangai	$H_{before} = 0.7116$	$H_{after} = 0.6735$
Market place	Ratio $x = \frac{H_{before}}{H_{after}}$	Rate of decrease $r = 1 - x$
Shenzen	$x = 0.9492$	$r = 0.0502$
Shangai	$x = 0.9465$	$r = 0.0535$

The rate of decrease of Hurst index is around 0.05 for both Shenzen and Shangai market. Let us recall that $H = 1/2$ corresponds to the efficiency of the market. So both market are evolving to efficiency, even if there are not entirely satisfying the market efficiency hypothesis.

Figures 2 and 3 show the evolution of the Hurst index over time, we see the overall evolution of the Hurst index in both markets, the trends are down for both markets and the Hurst indices are closer to 0.5. This long decline in the Hurst index is in line with our literature, that successive reforms and capital openings make Chinese markets increasingly efficient. However, as indicated by the Hurst indexes, the markets have come closer to efficiency without achieving it completely. Both markets are well below 0.5, which means that there is still much work and reform to be done to improve the efficiency of Chinese markets.

The reform of October 2011 corresponds at time t=1300 on the graphs of Figure 2 and Figure 3. We can see that the decrease on the estimated curves

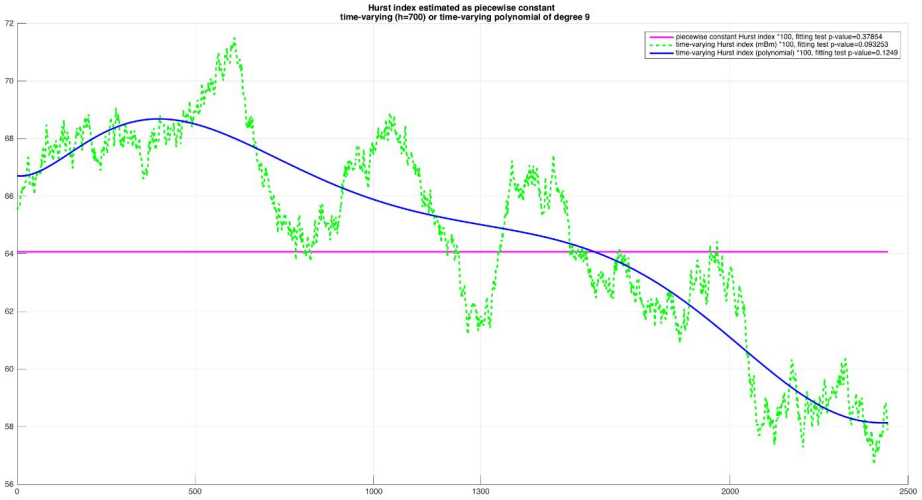

Fig. 2. Estimated Hurst index for Shenzhen market.

for H begins after time t=1300 There is also a shift in the efficiency trend in the Shanghai market (T = 2300 to T = 2500). This loss of efficiency can be explained by trade tensions between China and the United States, which have since emerged. When we finished this article, Chinese stock markets had plunged in a market worried by renewed trade tensions between Beijing and Washington. Detecting this change of trend in the evolution of the Hurst index only in the Shanghai market is quite understandable, because the Shanghai market includes more values and brings together all the economic sectors of the Chinese market, and therefore it better reflects China's economy, and is more sensitive to changing economic conditions. While the Shenzhen market is more focused on technology stocks. It is not surprising that there is a gap between these two markets.

5 Conclusion

With the transition to sustainable economic development, China's stocks pricing mechanism has been pushed toward a more market-oriented approach. We have used UCM to detect the presence of seasonality over the 2006 to 2019 period for the Shenzhen A-share market index and the Shanghai A-share market index. We hope to find an alteration in seasonal anomalies in the Chinese stock market. Although it would seem that in the Chinese stock market, the seasonal anomalies persist, the degree of efficiency has increased after the reform of October 2011. The Chinese stock markets are not efficient now, but they are running toward the direction of efficiency. This paper contributes to the current literature by examining the effects of the 2011 reform on the Chinese stock market return. The results have important implications for analyzing the influence of policies on

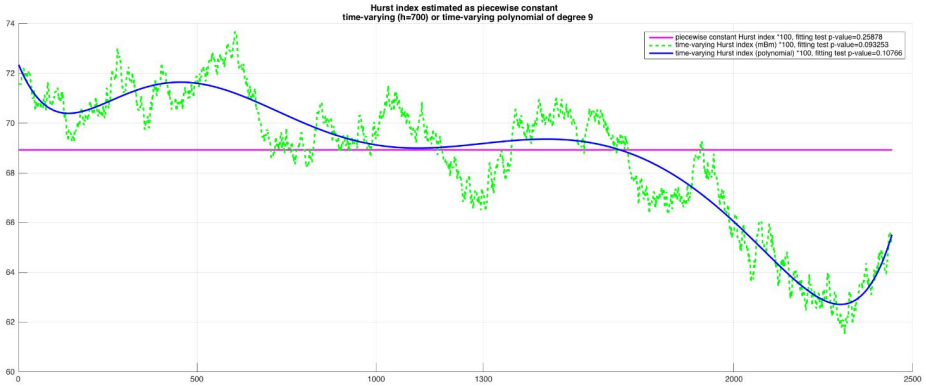

Fig. 3. Estimated Hurst index for Shanghai market.

the degree of market efficiency. This being said, a seasonality effect during certain periods does not necessarily imply a market inefficiency. For that, we have to show that investment strategy based on seasonality is capable of systematically beating the market. In this article, we focus on the day-of-week effects on the Shanghai stock index. For further analysis of seasonality in China, we think we have to analyse the Shenzhen Market Index and the monthly effect. These are subjects for further research.

References

1. Ayache A., and Taqqu M.S.: Multifractional processes with random exponent. Publicaciones Matematiques **49**(2) (2003) 459-486
2. Benassi A., Cohen S., and Istas J.: Identifying the multifractional function of a Gaussian process. Statistics & Probability Letters **39**(4) (1998) 337-345
3. Benassi A., Jaffard S., and Roux D.: Elliptic Gaussian random processes, Revista Matematica Iberoamericana **13**(1) (1997) 19-90
4. Benassi A., Bertrand P., Cohen S., and Istas J.: Identification of the Hurst index of a step fractional Brownian motion. Statistical Inference for Stochastic Processes **3**(1-2) (2000) 101-111
5. Bertrand P.R., Hamdouni A., and Khadhraoui S.: Modelling NASDAQ series by sparse multifractional Brownian motion. Methodology and Computing in Applied Probability **14**(1) (2012) 107-124
6. Bertrand P-R., Combes J-L., Dury M-E., and Hadouni D.: Overfitting of Hurst estimators for multifractional Brownian motion: A fitting test advocating simple models. Risk and Decision Analysis **7**(1-2) (2018) 31-49
7. Bianchi S., Frezza M.: Fractal stock markets: International evidence of dynamical (in)efficiency. Chaos **27**(7) 0711021 (2017)
8. Bianchi S., Pantanella A., Pianese A.: Efficient markets and behavioral finance: A comprehensive multifractional model. Advances in Complex Systems **18**(1) (2015)
9. Bianchi S., Pianese A.: Time-Varying Hurst-Hölder exponents and the dynamics of (in)efficiency in stock markets. Chaos, Solitons and Fractals **109** (2018) 64-75

10. Cross, F.: The behavior of stock prices on Fridays and Mondays. Financial Analyst Journal **29**(6) (1973) 67-69
11. Dury, M.-E.: Estimation du paramétre de Hurst de processus stables autosimilaires á accroissements stationnaires. Comptes Rendus de l'Académie des Sciences – Series I **333**(1) (2001) 45-48 [Into French.]
12. Fama, E.F.: Efficient capital markets: A review of theory and empirical work. The Journal of Finance **25**(2) (1970) 383-417
13. Fountas, S., and Segredakis, K.: Emerging stock markets return seasonalities: the January effect and the tax-loss selling hypothesis. Applied Financial Economics **12**(4) (2002) 291-299
14. French, K.: Stock returns and the weekend effect. Journal of Financial Economics **8**(1) (1980) 55-69
15. Geretto, E., and Pauluzzo, R.: Stock exchange markets in China: Structure and main problems. Transition Studies Reviews **19**(1) (2012) 89-106
16. Geske R., and Roll R.: The fiscal and monetary linkage between stock returns and inflation. Journal of Finance **38**(1) (1983) 1-33
17. Gibbons M.R., and Hess P.: Day of the week effects and asset returns. The Journal of Business **54**(4) (1981) 579-596
18. Girardin E., and Liu Z.: Bank credit and seasonal anomalies in China's stock markets. China Economic Review, **16**(4) (2005) 465-483
19. Gong, R., and Marsden, A.: The impact of the 2007 reforms on the level of information disclosure by the Chinese A-share market. China Economic Review **30** (2014) 221-234
20. Groenewold N., Tang S. H., and Wu, Y.: The efficiency of the Chinese stock market and the role of the banks. Journal of Asian Economics **14**(4) (2003) 593-609
21. Groenewold N., Tang S. H. K., and Wu Y.: The dynamic interrelationships between the Greater China share markets. China Economic Review **15**(1) (2004) 45-62
22. Guo B., Luo X., and Zhang, Z.: Sell in May and go away: Evidence from China. Finance Research Letters **11**(4) (2014) 362-368
23. Jacobsen B., Bouman S.: The Halloween Indicator, 'Sell in May and go away': Another puzzle. The American Economic Review **92**(5) (2002) 1618-1635
24. Kolmogorov A.N.: Wienersche Spiralen und einige andere interessante Kurven im Hilbertschen Raume. Doklady **26** (1940) 115-118 [Into German.]
25. Li K., and Lin B.: How does administrative pricing affect energy consumption and CO2 emissions in China? Renewable and sustainable energy reviews **42** (2015) 952-962
26. Li, X.: Asset pricing and share reforms: An anatomy of China's investable stocks. Asian-Pacific Financial Markets **21**(1) (2014) 15-34
27. Liu L., Wang Y., and Wan J.: Analysis of efficiency for Shenzhen stock market: Evidence from the source of multifractality. International Review of Financial Analysis **19**(4) (2010) 237-241
28. Mandelbrot B., and Van Ness J.W.: Fractional Brownian motions, fractional noises and applications. SIAM Review **10**(4) (1968) 422-437
29. Mobarek A., and Fiorante A: The prospects of BRIC countries: Testing weak-form market efficiency. Research in international business and finance **30** (2014) 280-290
30. Mookerjee R., and Yu Q.: Seasonality in returns on the Chinese stock markets: the case of Shanghai and Shenzhen. Global Finance Journal **10**(1) (1999) 93-105
31. Peng Q.: Financial frictions, entry and growth: A study of China. Review of economic dynamics **34** (2019) 267-282

32. Ramasamy R., and Munisamy S.: Predictive accuracy of GARCH, GJR and EGARCH models select exchange rates application. Global Journal of Management and Business Research **12**(15) (2012) 1-12
33. Rogalski J. R.: New findings regarding day of the week returns over trading and non-trading periods: A note. Journal of Finance **39**(5) (1984) 1603-1614
34. Tan L., Chiang T., Mason J.R., and Nelling E.: Herding behavior in Chinese stock markets: An examination of A and B shares. Pacific-Basin Financial Journal **16**(1-2) (2008) 61-77
35. Wang Y., Liu L., and Gu R.: Analysis of efficiency for Shenzhen stock market based on multifractal detrended fluctuation analysis. International review of financial analysis **18**(5) (2009) 271-276
36. Wen X., Bouri E., and Roubaud D.:Does oil product pricing reform increase returns and uncertainty in the Chinese stock market? The Quartely Review of Economics and Finance **68**(C) (2018) 23-30
37. Xiao B.: The monthly effect and the day of week effect in the American stock market. International Journal of Financial Research **7**(2) (2016) 11-17
38. Yu, B., Sutthisit J., and Wu S.: Trading behaviors in Chinese stock markets: Empirical evidence from Shanghai, Shenzhen, and Hong Kong stock exchanges. Journal of Financial and Economic Practice **12**(1) (2012) 41-65

Mathematical Methods in Economics and Finance – m^{2}ef
Vol. 13/14, No. 1, 2018/2019
ISSN print edition: 1971-6419 – ISSN online edition: 1971-3878
Web page: `http://www.unive.it/m2ef/` – E-mail: `m2ef@unive.it`